

CHAPTER 7

WATER TREATMENT

LEARNING OBJECTIVE: *Recognize methodology used for water treatment and purification; understand and identify types of water treatment equipment, treatment processes, and water testing procedures.*

Water is never absolutely pure. Impurities in water vary from dissolved gases, chemicals and minerals, to suspended matter, like disease germs and dirt. Some impurities can be seen and some cannot; others can be detected by taste or odor or only by laboratory tests. This chapter explains the water cycle, the quality of water, the chlorination equipment, the water treatment quality control and water testing procedures. Water treatment is vital to the health and well-being of the troops. Improper treatment of water can allow the spread of infectious intestinal diseases and skin fungus. The unit commander and the Navy Medical Service share responsibility of ensuring a supply of pure water in the Seabees. As a Utilitiesman, you will perform major duties involving the treatment and purification of water, so it is safe to use for drinking, cooking, and bathing.

THE WATER CYCLE

LEARNING OBJECTIVE: *Understand the hydrologic cycle and sources of water.*

Water is circulated from the oceans to the atmosphere by a series of processes and then to the surface of the earth and beneath it. This is known as the water cycle, or hydrologic cycle (fig. 7-1). An understanding of the occurrence of groundwater is based on a general knowledge of these processes and their relationships to each other. Basically, the cycle consists of the following processes:

- Evaporation of water from oceans
- Condensation of the water to produce cloud formations
- Precipitation of rain, snow, sleet, or hail upon the land surface
- Dissipation of the water by direct runoff into lakes and streams

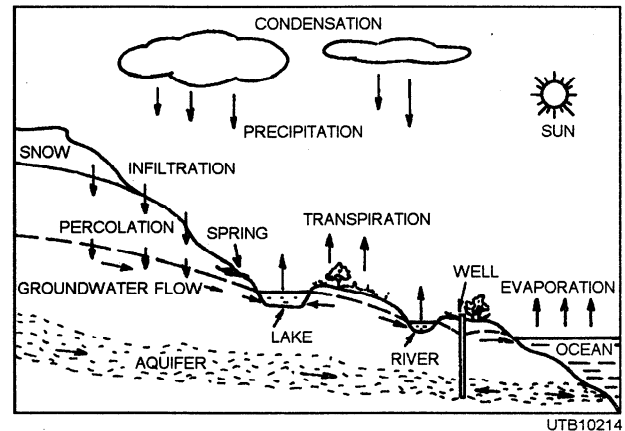


Figure 7-1.—The hydrologic cycle.

- Seepage, or infiltration, of rainwater or melted snow into the soil and then into underlying rock formations
- Movement of water through the openings in the rocks and at the surface through springs, streams, and lakes
- Direct evaporation

The cycle usually does not progress through a regular sequence and may be interrupted or short-circuited at any point. Moisture that condenses over the ocean may fall into it as rain. Rain that falls upon a heavily forested area soon may return to the atmosphere by direct evaporation or through transpiration by plants. Jungle-covered islands of the Southwest Pacific are known to produce more evaporation than adjacent areas of ocean. Water that seeps into the soil may be retained for a time by soil capillarity, or other means, before moving downward through the unsaturated zone to become a part of the groundwater.

As the rainfall and water cycle repeats itself, depending upon climatic and other conditions, a water supply is built up that can be captured and used for a

multitude of purposes. Roughly, this basic water supply is divided into two categories-surface water and groundwater.

SURFACE WATER

Surface water is water that is flowing in our streams or rivers, resting in our lakes and ponds, or flowing into the sea. Its origin lies in the water that falls from the atmosphere, together with that which flows from the ground under certain circumstances. The water precipitated upon the surface of the earth from the atmosphere can be in the form of rain, snow, sleet, fog, or dew. Depending upon the character of the soil, this precipitated moisture is partly absorbed by the soil, partly evaporated or transpired by plant growth with the remainder caught in surface depressions or flowing over the surface to natural stream beds where it continues on its way to the sea or into the crevices of the earth. In olden days, it was thought that the vast underground water storage reservoirs were tied by surface streams. This is only partly true. In many cases where geological conditions permit, the groundwater sources feed the stream instead. It is true that the underlying beds of some surface streams are composed of sand and gravel and other materials deposited through the ages by sedimentation or glacial action. In these cases, water from the stream sometimes trickles down by gravity through the stream bottom into the underlying sands or gravel. When this happens, the water in the bottom gravel generally flows in the same direction as the stream itself. In other cases, it may be held in storage by natural barriers in the path of its flow. These underlying sands and gravel, generally referred to as "alluvium," are discussed in the section covering groundwater. In many cases, riverbeds become completely dry while the flow through the alluvium continues. This occurs in many cases in the western sections of the United States and on the Pacific Coast of North America.

GROUNDWATER

Groundwater is that part of the water or moisture that has precipitated from the atmosphere upon the surface of the earth and has been absorbed by the soil and collected below a certain level called the "water line." The waterline is of utmost importance and interest. The uppermost part of the surface of the earth is composed of layers of materials of a varying nature. There is a topsoil capable of sustaining plant growth. This topsoil is composed largely of minute particles of rock mixed with decayed vegetable matter

or other material. A layer of material generally referred to as "soil" underlies the topsoil. Soil is composed of minute particles of rock mixed with various materials, sometimes of vegetable or animal origin, but often containing nothing more than materials of mineral origin. The depth of the soil bed is not fixed and may vary from a few inches to several feet.

Under the soil layer is the top layer of rock, which is decomposed in some measure and which at a deeper level becomes more solid. Ultimately this rock becomes solid, as it was in the original cooling process. That part of the crust of the earth between this solid rock and the surface of the earth is of interest in discussing groundwater. Again, the depth of this outer layer is a variable because in many locations the virgin rock appears at the surface with no overlying decomposed rock or soil. Certainly, groundwater could not be found at such locations.

Now, consider the layer of decomposed rock which is between the uppermost layer of soil and the solid or virgin rock itself. Here, during the ages, many things have happened. The action of the elements, atmospheric conditions, earthquakes and upheavals, volcanic action and chemical reactions, as well as pressure conditions and other influences, have caused this layer to become anything from a semisolid rock to a conglomeration of layers of various materials. These layers of materials are referred to as "strata." The layers normally follow the contour of the surface of the earth; however, in some cases, they outcrop at the surface and slant downward. These strata may be composed of sand, gravel, broken stone of all sizes and character, minerals of all kinds, and even layers of solid rock. Some of the softer materials are shales, chalk, clays, and gypsum. The harder materials consist of limestone, granite, quartzite, flint, silica, dolomite, and other minerals. The types of material depend on the geographical location and the conditions under which the top most layers of rock were formed. In the formation process, because of earth movement and other influences, these varying strata were bent, folded, and broken in such fashion that it is not possible to chart their exact course through the upper part of the crust of the earth. Their presence and their position relative to each other are important to the storage and production of groundwater.

Depending upon the composition of these various strata, they either absorb the water which falls from the sky or flows at a level above them, or they reject this water and form a bed upon which the water flows in one direction or the other. The capacity of the material

composing any stratum to transmit water under pressure is called its “permeability.” The property of the material of any stratum to contain interstices, or openings, is called its “porosity.” Both the permeability and porosity of the rock formation determine whether groundwater can be found in suitable amounts at any particular location.

When water falls on the ground, the part of it that becomes groundwater by reason of the soil or surface characteristics is absorbed into the earth. It is then either held in suspension or flows downward by gravity to a point beyond which it cannot pass. It then flows in any direction provided the permeability of the particular stratum holding it permits. When the permeability of the stratum does not permit flow, the water remains confined at that point. As more water percolates downward through the soil or rock, the top level of the confined water rises until flow becomes possible in one direction or the other through a more permeable formation. More water must come from a higher level to sustain such a flow. Finally, the amount of water percolating from the higher levels balances the amount of water flowing laterally away, and the top level of the main body of groundwater is stabilized. The upper surface of this main body of groundwater, when stabilized under any condition of flow, constitutes the water table for any specific locality. However, the water table is not fixed because it rises and falls according to the varying amounts of water percolating from above (called the “influent” supply) and those amounts flowing away or withdrawn (called the “effluent” flow). A stratum that bears groundwater is termed an aquifer.

Water beneath the surface of the earth occurs in three zones (fig. 7-2) as follows:

1. The zone of soil moisture is where water is temporarily held in pore spaces by capillarity and other soil conditions. Water in the zone of soil moisture may evaporate directly or through transpiration by plants or it may percolate downward into the zone of aeration and then to the zone of saturation.

2. The zone of aeration, or zone of percolation, is beneath the soil layer where both water and air are present in the pore spaces. Wells ending in the zone of aeration produce no water. Sometimes in the cooling-off process or because of other external and internal influences, a stratum of material that does not permit the passage of water has been heaved about into a cup-shaped formation at a point in the zone of aeration higher than the established water table. In time, this cup is filled with groundwater and a “perched” or false

water table is established. This is a serious problem to those attempting to develop a groundwater supply. The perched supply, if pumped, is soon exhausted and requires seepage from above for replenishment. Many of these perched supplies result from folded clay formations in the zone of aeration that stop the percolation of water downward. Perched water never forms a dependable water supply.

3. The zone of saturation is where all pore spaces are filled with water. The top of the saturated zone is called the “water table.” It is not flat, but has a variable depth beneath the surface, depending upon surface topography, rainfall, and direction of water movement, rock structure, and porosity. Permeable rocks in the zone of saturation yield water to wells.

Q1. What are the two categories of water?

Q2. What are the three zones of subsurface groundwater?

THE QUALITY OF WATER

LEARNING OBJECTIVE: *Identify and understand types of waterborne diseases, impurities in water, and types of treatment processes.*

Preliminary to discussion of water production, the “quality” of available water supplies must be briefly considered. Whether the water supply comes from the surface or underground, the supply must suit its intended use. Either source may produce water with too high a concentration of mineral salts, color, suspended matter, incrusting or corrosive agents, or bacteria that prevents the use of water in its natural state for the purpose intended. If suitable water cannot be found, then other available sources must be used. The water must be treated to remove those elements that make its direct use impossible. For human consumption, all harmful bacteria must be destroyed and the concentration of certain mineral salts and

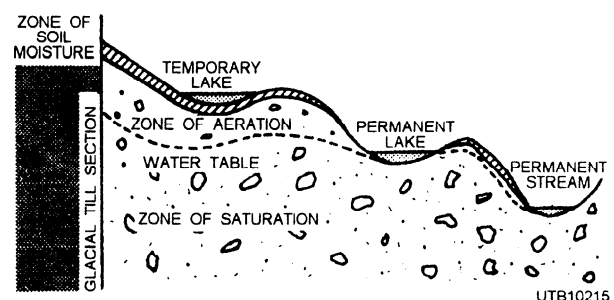


Figure 7-2.—Classification of underground water.

suspended matter reduced to a level that makes the water safe to drink or to use in preparing food. Industries 'sometimes have to treat their raw-water supply to meet the requirements of the manufacturing processes. Boiler feedwater must often be treated to prevent sludge from forming in the boiler and scale from forming on the metal surfaces. Most towns and municipalities must treat their water supply by some method before distributing it as potable water. Water, whatever the source, must be available in quantity and quality to meet its intended use.

WATERBORNE DISEASES

In this section, various diseases caused by the use of water that is impure and unsafe are discussed. Some of the methods of treatment and purification used in the field to eliminate impurities in water are also discussed. Additionally, you are introduced to types of purification equipment with which you, as a Utilitiesman, should be familiar.

Water flowing over the surface of the earth picks up dirt, disease organisms, chemicals, and anything else in its path that can be dissolved or moved. Water that soaks into the ground loses many of its suspended impurities, as it filters through the earth. Although the water becomes clearer, it dissolves minerals and other chemicals at the same time. Groundwater may be clear, but it is not pure and may contain harmful disease organisms and chemicals.

Waterborne diseases do not appear immediately after drinking contaminated water. Disease-producing organisms need time to grow and multiply inside a person before they cause illness. The time between drinking contaminated water and the appearance of the disease is called the incubation period. Absence of disease symptoms for several days after drinking untreated water is no guarantee that the water is pure. Lack of disease symptoms in the natives is no test either, as they may have become immune.

IMPURITIES IN WATER

Any water supply can be a source of danger and destruction because of the many impurities often found in it. Impurities in water can be broken down into two major categories-dissolved impurities and suspended impurities. **DISSOLVED IMPURITIES** are organic or inorganic materials or chemicals that cause an unpleasant taste, color, or odor in the water. **SUSPENDED IMPURITIES** include organisms as well as organic and inorganic materials that usually

make the water turbid or muddy looking. Suspended impurities are usually more dangerous to health than dissolved impurities. The suspended impurities consist of mineral matter, such as sand, silt, or clay; of disease organisms, such as bacteria or protozoa; and of water plants, such as algae. It is absolutely necessary to remove or destroy the disease-producing organisms in water that will be consumed by people.

TYPES OF WATERBORNE DISEASES

Water carries many of the organisms that produce disease. Disease-producing organisms carried by water occur in two classes-those readily destroyed by chlorination and those that are chlorine resistant. Although the chlorine-resistant organisms require careful treatment, they can be destroyed by purification methods. Waterborne diseases caused by dangerous organisms include typhoid, paratyphoid, cholera, amoebic dysentery, schistosomiasis, and diarrhea. The following discussion stresses continual care and inspection of the water supply, because waterborne diseases spread if not treated properly.

Typhoid Fever

TYPHOID FEVER is an intestinal disease caused by the bacterium known as *bacillus typhosus*. Symptoms of this disease are rose-colored eruptions of the skin, accompanied by a high fever (lasting about 4 weeks) and frequent bowel movements. Typhoid fever organisms are readily destroyed by field chlorination methods. Most waterborne diseases do not appear immediately after using contaminated water, as they need time to grow after entering a person's system. The time to grow is the incubation period.

Paratyphoid Fever

PARATYPHOID FEVER is similar to typhoid in sources of infection and in symptoms; the organisms are, like the typhoid bacillus, readily destroyed by field chlorination methods. The incubation period varies from 4 to 10 days. An attack gives a person immunity from a second attack of paratyphoid, but does not give immunity from typhoid.

Cholera

CHOLERA germs are discharged from the body in feces where they live for several days. When water in any form contacts this germ, it is carried along and multiplies.

Amoebic Dysentery

AMOEBIC DYSENTERY is an infectious intestinal disease. Symptoms are eruptions of the skin and frequent bowel movements. This disease is caused by a small animal instead of bacteria and resists ordinary chlorination. It is carried by amoebic cysts that foray in the intestines, then are discharged in the feces. Cysts (shell or sack) protect them and, when in water or moistened, they live for many days, but drying destroys them. The diatomite filter removes the cysts and super chlorination destroys them.

Schistosomiasis

SCHISTOSOMIASIS is caused by a small worm that enters the body through consumption of contaminated water. Or, it may enter through the skin while a person is bathing or swimming in contaminated water. Eggs of this parasite (commonly called blood flukes) are discharged from an infected person through the urine or feces. In fresh water, these eggs hatch into very small, free-swimming larvae which are not infectious to humans. However, if these larvae can find freshwater snails to enter, they develop into the next form "cercariae," and become highly infectious to human beings. In water, larvae can live for only 24 hours and cercariae for only 36 hours. The effective remedy is to destroy all the snails at the water source. Once the snails are destroyed, the cycle is broken and the disease ceases.

Diarrhea

DIARRHEA is a name given to several intestinal diseases characterized by cramps and frequent bowel movements with watery feces. Inadequate sanitary protection of food and water can cause diarrhea. When the disease is caused by food, it is restricted to those who consume the contaminated food; however, waterborne infection is likely to be widespread. Proper chlorination measures will eliminate waterborne diarrhea.

In addition to the specific waterborne diseases discussed above, there are several nonspecific disorders caused by impure water. One example is the staining or discoloring of teeth because of the presence of fluorides in drinking water.

TREATMENT AND PURIFICATION OF WATER

Various methods of treatment and purification are used to eliminate impurities in water and make it

pleasant to drink. You should be familiar with some of the principal methods commonly used, keeping in mind that safe, pure water is essential to naval operations everywhere. How well you carry out your duties in the treatment and purification of water concerns the health and welfare of all personnel using the water. Methods used in various combinations of field treatment and purification of water include coagulation, flocculation, sedimentation, filtration, and disinfection.

Flocculation

COAGULATION is a formation of gelatinous particles in water by chemical action. FLOCCULATION is the combination of these particles into a heavy precipitate (floc) that absorbs color and entangles bacteria and other suspended matter, as it settles. A common floc-forming chemical is aluminum sulfate (filter alum). When sufficient natural alkali is not present in the water to form a good floc, additional alkali (soda ash) must be added. Figure 7-3 shows how flocculation works. Mechanical devices, such as mixers, agitators, and baffles, are an advantage in flocculation because they keep the precipitate suspended in the water long enough to produce a heavy floc.

Sedimentation

If you were to dip up a glassful of water from a moving stream and proceed promptly to observe its contents, you would probably discover a number of solid particles being held in suspension in the liquid. At first these particles are more or less equally dispersed; but as the water becomes still, they start settling to the bottom of the glass. The settling of solids in this manner is caused by the natural action of gravity. In the field of water treatment, clearing water

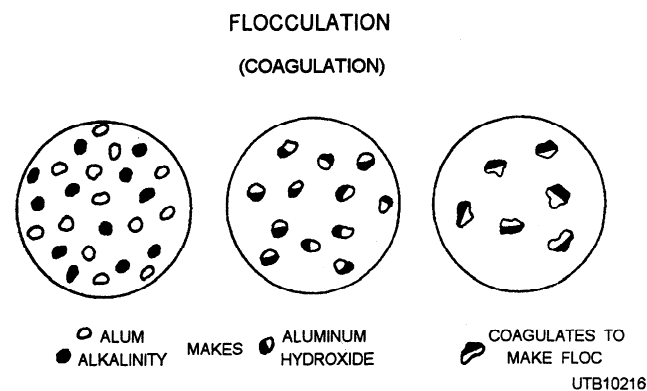


Figure 7-3.—The process of flocculation.

of turbidity (that is foreign suspended matter) by this natural settling process is known as **SEDIMENTATION**. Sedimentation is accomplished in settling tanks where the water is held for a time to allow the floc to form and settle out turbidity. In conventional treatment, settling immediately follows flocculation. The ideal detention period for settling after slow mixing is about 1 1/2 hours.

Filtration

Not all suspended matter is removed by sedimentation. Therefore, another process known as **FILTRATION** is used. An effective type of filter used in the filtration process is the diatomite. Because it is lightweight, this filter is widely used at overseas bases. It removes suspended matter from water by passing it through a porous mat of diatomaceous silica. Diatomaceous silica is the skeletal remains of tiny algae, called diatoms, found in marine deposits that have been lifted above sea level. The diatomite (also called diatomaceous earth or filter aid) is supported by a filter element. This supporting base is porous enough to permit maximum flow. It is also fine enough to support the filter cake that coats the element. Diatomite filters are backwashed by reversing the flow of water and drawing filtered water through the filter to keep the filter output from falling off. The turbidity of the water is largely determined by the frequency of backwash.

Disinfection

Except in rare instances, all water supplies require disinfection. Disinfection is the chemical destruction of bacteria. Because of its economy, dependability, efficiency, and ease of handling, chlorine is almost always used for this purpose. For this reason, the term *chlorination* generally means the same as **DISINFECTION**.

Disinfection is a necessary step in ensuring a safe water supply. All new, altered, or repaired water-supply facilities must be disinfected before they are placed in service. Water from surface supplies may be disinfected before filtration or before coagulation and sedimentation to prevent the growth of organisms. This procedure is known as *prechlorination*. The water must also be disinfected after filtration to destroy organisms that still remain and to provide a safeguard against recontamination. This procedure is known as *postchlorination*.

Chlorine is the disinfectant specified for Navy use. In the form of chlorine gas or of hypochlorites that

yield chlorine in water, chlorine is presently the only widely accepted agent that destroys organisms in the water and leaves an easily detectable residual that serves as an indicator of the completeness of treatment. The sudden disappearance of residual chlorine may signal contamination in the system. Under ordinary temperatures and pressures, chlorine gas is greenish yellow and is heavier than air. Its effectiveness as a disinfectant depends on the temperature and the hydrogen-ion concentration (pH) of the water to which it is added. Disinfecting action is faster at higher temperatures, but is retarded by pH. When the pH is above 8.4, the rate of disinfection decreases sharply.

Ozone, potassium permanganate, bromine, and iodine are also used to a limited extent as disinfectants. If excess lime is used for softening water, it makes the water alkaline and disinfects after about 10 hours of contact. However, the general applicability and economic advantage of chlorine have established it as the preferred disinfectant.

CHLORINE DISINFECTION.—Chlorine disinfectants are available in a number of different forms as described in the following paragraphs

LIQUID CHLORINE is liquefied gas under pressure and is shipped in seamless steel cylinders under the regulations established by the Interstate Commerce Commission. The standard sizes of shipping containers are 150-pound cylinders, 1-ton containers, and 30-ton tank trailers.

Each pound of liquid chlorine produces about 5 cubic feet of chlorine gas at atmospheric pressure and at a temperature of 68°F. A standard Chlorine Institute valve and a protective valve hood are screwed into the neck of each cylinder. The valve has a safety plug containing fusible metal that softens between 157°F and 162°F to protect the cylinder from bursting in case of fire. All cylinders must be factory tested every 5 years; 150-pound cylinders are tested at 500 pounds of pressure; and 1-ton containers are tested at 800 pounds of pressure.

HIGH-TEST CALCIUM HYPOCHLORITE is a relatively stable, dry granular solid or powder that is readily soluble to form a chlorine solution. Prepared under a number of trade names, including HTH, Perchlaron, and Pittchlor, it is furnished in 3- to 100-pound containers and has 65 to 70 percent available chlorine by weight. Because of its concentrated form and ease of handling, calcium hypochlorite is preferred over other hypochlorites.

SODIUM HYPOCHLORITE is generally furnished as a solution that is highly alkaline, and therefore reasonably stable. Federal specifications call for solutions with 5 and 10 percent available chlorine by weight. Shipping costs limit its use to areas where it is available locally. It is also furnished as powder under various trade names, such as Lobax and HTH-15. The powder generally consists of calcium hypochlorite and soda ash that react in water to form sodium hypochlorite. Ordinary household bleach is a sodium hypochlorite solution containing 2.5 percent available chlorine and is sometimes used at small installations.

CHLORINATED LIME, also known as **CHLORIDE OF LIME** or **BLEACHING POWDER**, is seldom used in water disinfection. It is a mixture of calcium chloride and calcium oxychloride that yields about 35 percent available chlorine when fresh. It deteriorates rapidly in a hot, moist atmosphere and should be purchased in small packages that can be kept sealed. Chlorinated lime contains an excess of insoluble lime; therefore, the solution should be prepared in a separate container, the lime permitted to settle, and the liquid decanted into a separate tank for use.

CHLORINE TERMS.—When chlorine gas is introduced into pure water, some of it reacts to form hypochlorous acid, and the rest remains as dissolved chlorine. These forms of chlorine are termed *free available chlorine* because their oxidizing and disinfecting ability is fully available. Because most natural water contains small amounts of ammonia and nitrogenous organic substances, free available chlorine reacts with these substances to form chloramines and other complex chlorine-nitrogen compounds. These forms of chlorine compounds are termed *combined available chlorine* because part of the chlorine oxidizing disinfecting ability is lost. Both free available chlorine and combined chlorine react with oxidizable substances in water until their oxidizing and disinfecting ability is depleted. The amount of chlorine consumed in reacting with organic substances in water in a given time (usually 10 minutes) is called the **CHLORINE DEMAND**. Chlorine remaining in excess of the chlorine demand is the **TOTAL CHLORINE RESIDUAL** or **RESIDUAL CHLORINE**. Residual chlorine is composed of both free available chlorine and combined available chlorine. The time elapsing between the introduction of chlorine and use of the water is 30 minutes and is termed the *contact period*.

BACTERICIDAL EFFECTIVENESS.—The bactericidal effectiveness of chlorine depends upon the pH chlorine residual, contact period, and temperature. The pH value is a measure of the acidic or alkaline nature of the water. The pH of water is technically defined as the negative logarithm of the hydrogen ion concentration. The pH value ranges from 0 to 14. A value of 7 is neutral. Values decreasing downward from 7 represent increasing numbers of hydrogen ions. Values increasing upward from 7 represent decreasing numbers of hydrogen ions. A low pH value indicates a very strong acid solution. A high pH value indicates a very strong alkaline solution. The alkalinity of water is the amount of “alkaline” substances in a given sample of water when titrating downward to a pH of 4.2 with sulfuric acid. The acidity of water is the amount of “acid” substances in a given sample of water when titrating upward to a pH of 4.2 with sodium carbonate. The pH value of natural water can vary from 3.4 to 9.0, depending on the impurities present in the water.

The pH influences the corrosiveness of the water, the amount of chemical dosages necessary for proper disinfection, and the ability of an analyst to detect contaminants. The pH scale is shown in figure 7-4.

Chlorine effectiveness increases rapidly with an increase in the residual. However, free available chlorine is 20 to 30 times as effective as combined chlorine under the most favorable conditions of pH (7.0) and water temperature (68°F to 77°F). Therefore, the relative amounts of free and combined available chlorine in the total residual are important.

Within normal limits, the higher the chlorine residual, the lower the required contact period. If the residual is halved, the required contact period is doubled. The effectiveness of free available chlorine at 35°F to 40°F is approximately half of what it is at 70°F to 75°F. The effectiveness of free chlorine is highest at pH 7 and below. At pH 8.5, it is one sixth as effective as at pH 7, and at pH 9.8, it may require 10 to 100 times as long for a 99 percent bacteria kill as at pH 7.

POINTS OF APPLICATION.—Plain or simple chlorination is the single application of chlorine as the

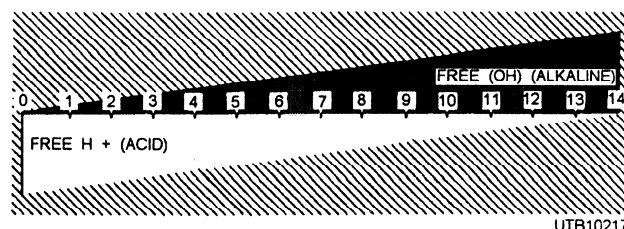


Figure 7-4.—The pH scale.

only treatment before discharge to the distribution system, as in the chlorination of groundwater supplies and previously unchlorinated purchased supplies. Prechlorination is the application of chlorine to raw water before coagulation, sedimentation, or filtration. Postchlorination is the application of chlorine after filtration, but before the water leaves the treatment plant. Rechlorination is the application of chlorine into the distribution system or into a previously chlorinated purchased supply to maintain the chlorine residual.

The above applications are normally continuous. Very heavy chlorination for a limited period is sometimes applied at specific points in the distribution system to destroy localized contamination.

OTHER USES OF CHLORINE.—Chlorine is also used to control tastes and odors in water. It reacts with the substances causing taste and odor, such as hydrogen sulfide, minute organisms, algae, and organic compounds.

If the reaction is incomplete, the taste and odor of some substances may be intensified or become more objectionable. Chlorine is also used to a limited extent to oxidize iron and manganese and to remove color.

SAFETY.—Safety is important in the handling of chlorine. Some of these important factors are as follows:

- Provide self-generating oxygen-breathing apparatus or self-contained oxygen-breathing apparatus designed to cope with chlorine.
- Maintain only the supply of chlorine in any chlorinator room that will do for normal daily demands. Store the main supply in a detached noncombustible building or in a fireproof room that is vented only to the outside and separated from the main part of the building. Keep the chlorinator and chlorine storage building or rooms locked to prevent the entrance of unauthorized personnel and restrict these areas from any other use.
- Allow only reliable and trained personnel to handle chlorine.
- Handle containers carefully to avoid dropping or bumping them.
- Avoid hoisting containers; if hoisting is necessary, use safe lifting clamps.
- Store cylinders in a cool place, away from dampness, steam lines and fire, and in an upright position secured from tilting and falling.

- Keep protective valve caps on containers when not in use; never tamper with safety devices on containers.
- Never connect a full cylinder to a manifold with another cylinder unless the temperatures of both are nearly the same.
- When not withdrawing chlorine or when cylinders are empty, keep the valves closed.
- Disconnect the valves as soon as the containers are empty, and check for chlorine leaks at the valve outlets. Test for leaks by passing an opened bottle of strong ammonia solution around the valve. White fumes of ammonium chloride will appear if there is any leakage. Leaks around fittings, connections, and line can be detected in the same way. Do not apply ammonia solution to plated metal parts, as it will remove the plating.
- When chlorine is noticed, workers should avoid panic, refrain from coughing, keep mouth closed, avoid deep breathing, keep head high, and get out of the affected area. Only qualified personnel with suitable respiratory equipment should be assigned to investigate and correct the cause of chlorine leaks. If chlorine is being discharged, close the container valve immediately. If chlorine is escaping in liquid form, turn the containers so the chlorine escapes as gas. This will reduce leakage. Do not apply water to the leak; this dangerous practice causes corrosion that may increase the leakage. Electronic chlorine gas detector warning devices are widely used in plants and mechanical rooms that contain chlorine.
- The handling of a persistent chlorine leak in a plant is best left to the chlorine supplier or local fire department.
- Never apply a flame, blowtorch, or other direct heat to chlorine containers; discharge them in a room with a temperature of about 70°F.
- Never ship a defective or leaky cylinder unless it is completely empty. Paint “DEFECTIVE” plainly on all such cylinders.
- Follow all regulations on shipping, storing, and using compressed gas cylinders.
- Provide proper means of exit from areas where chlorine is stored or used.
- Never use a chlorine cylinder except to hold chlorine gas.

- Q3. *In reference to waterborne diseases, what does "incubation period" mean?*
- Q4. *What are the two major categories of impurities in water?*
- Q5. *Eruptions of the skin and frequent bowel movements, without fever are symptoms of what waterborne disease?*
- Q6. *Natural gravity action is the mechanism for what method of water treatment?*
- Q7. *What is the most commonly used disinfectant in water treatment?*

CHLORINATION EQUIPMENT

LEARNING OBJECTIVE: *Recognize types, functions, and safety precautions associated with chlorinators.*

Chlorination equipment used to feed chlorine gas or hypochlorite solution may be classified by type, depending on the methods of control. The three methods of control are manual, semiautomatic, and fully automatic.

1. The manually controlled type equipment must be started and stopped manually, and the rate of feed must be manually adjusted to the rate of water flow.
2. In the semiautomatic type, equipment starts and stops automatically as water flow starts and stops; however, it must be manually adjusted to the rate of water flow. This type is normally used with water pumped at a fairly uniform rate.
3. In the fully automatic type, the rate of feed is automatically adjusted to the rate of flow of the water being treated through pressure of a metering device.

In all three types, the ratio of feed to water treated, or dosage, is set by manual adjustment.

Chlorinators may also be classified generally by type of feed. Here you have two types of machines—DIRECT-FEED and SOLUTION-FEED. Direct-feed machines are designed to operate without a pressure water supply, feeding the chlorine gas directly into the flow to be treated. Solution-feed machines dissolve the gas in a minor flow of water and inject the resultant solution into the flow to be treated and require a pressure water supply for operation.

Another method of classifying chlorinators is by the type of diaphragm used in controlling the chlorine feed. There are two types—the water diaphragm and

the mechanical diaphragm. The water diaphragm is always a vacuum type, solution-feed machine and has the advantages of being friction-free and punctureproof. The mechanical diaphragm machine may be either direct- or solution-feed pressure type or solution-feed vacuum type only.

DIRECT-FEED CHLORINATORS

Direct-feed chlorinators are used chiefly as emergency equipment and on small installations where it is not possible to obtain a water supply suitable for operating a solution-feed machine. They cannot be used where the pressure of the water being treated is more than 20 psi and are limited in the types of semiautomatic and automatic controls that may be used. Because the chlorine is under pressure as a gas at all times, direct-feed machines may easily leak gas into a confined or poorly ventilated space where the leakage could corrode adjacent equipment and structures. If you should be called upon to operate a direct-feed chlorinator, carefully follow the recommendations and instructions of the equipment manufacturer. You, as the operator, must be thoroughly familiar with the equipment to ensure its proper operation, adjustment, and minor repair.

SOLUTION-FEED CHLORINATORS

A solution-feed chlorinator introduces chlorine gas into the water supply by means of a chlorine solution. This supply is usually formed by drawing chlorine gas into a jet stream of water at the low-pressure point of the injector mechanism of the chlorinator.

The chlorinator (figs. 7-5 and 7-6) controls and indicates the rate of flow of chlorine; provides a simple means of manually setting the feed rate; mixes chlorine gas and water; and delivers the solution to the point of application. Figures 7-7 and 7-8 show a typical cylinder connection and scales.

The chlorinator operates under a vacuum, produced by a flow of water through the injector. The installation must allow a 5-inch vacuum.

Chlorine gas under pressure enters the chlorinator at the chlorine inlet connection where it is electrically heated to reduce the deposit of impurities and to prevent reliquefaction of the gas when the chlorinator is shut down with the supply turned on. Chlorine expands into a gas at a ratio of 1:460; that is, 1 cubic inch of chlorine expands into 460 cubic inches of gas. This volumetric expansion can rupture lines. For the same reason, there should be no dips or traps in any piping installation.

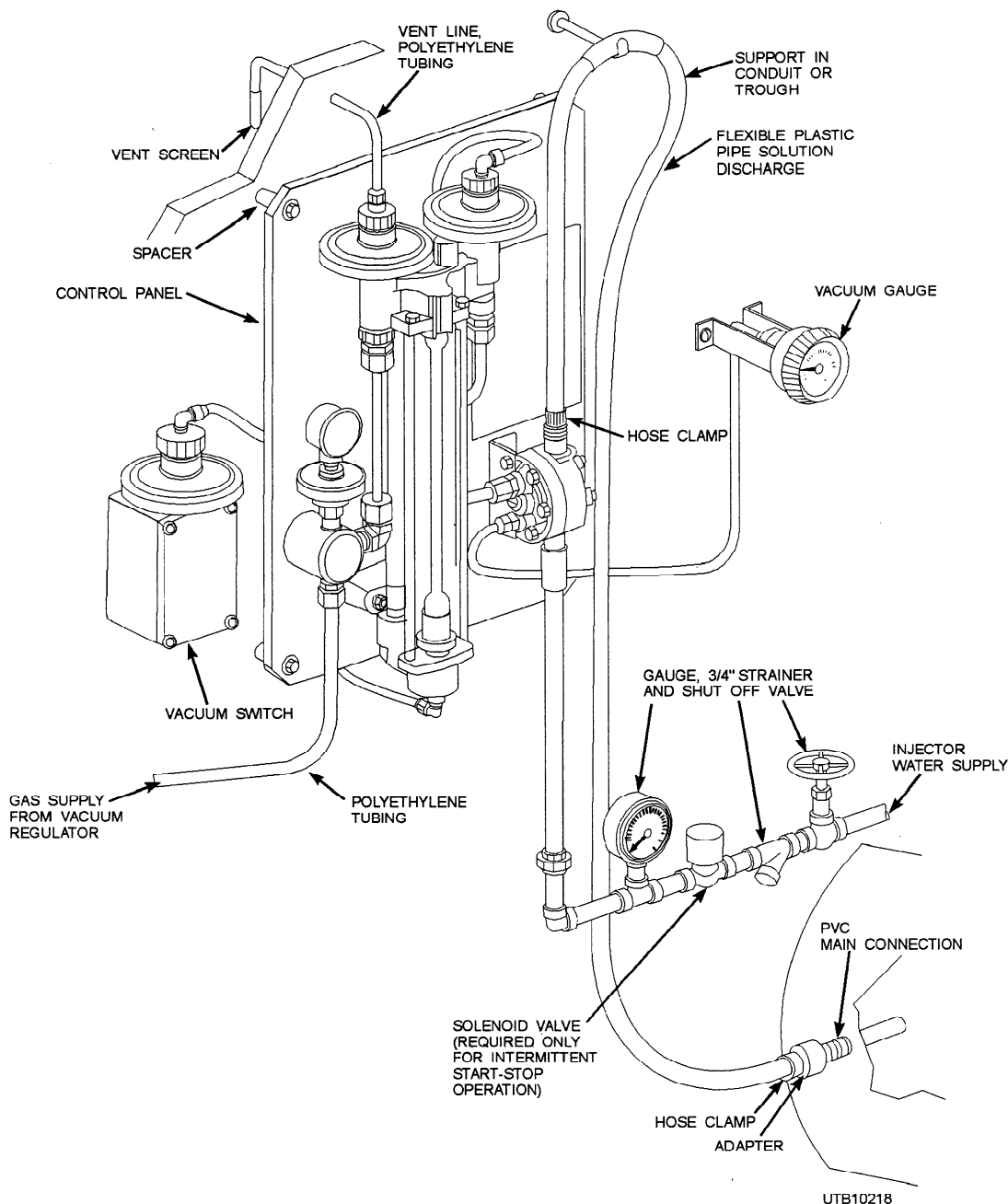


Figure 7-5.—V-Notch Gas Feeder-typical installation, 3 to 200 lb/24 hr.

Figure 7-7 shows a typical chlorine piping installation. A vacuum will pull on the diaphragm in the gas pressure-regulating valve and open the inlet valve. The entrance of chlorine will hold this vacuum at a fairly constant value. Since the vacuum on the upstream side of the V-notch variable orifice is somewhat higher, the vacuum-regulating valve is designed to maintain a constant drop across the V-notch variable orifice. The V-notch plug can be manually, electrically, or pneumatically operated.

NOTE: For variable vacuum operation, the injector vacuum must be at least 10 inches of mercury.

OTHER TYPES OF CHLORINATORS

You may find other types of chlorinators at naval activities. Among other types that may be at your activity are the vacuum-type mechanical-diaphragm chlorinator, the volumetric vacuum-type chlorinator, the vacuum-type diaphragm-controlled chlorinator,

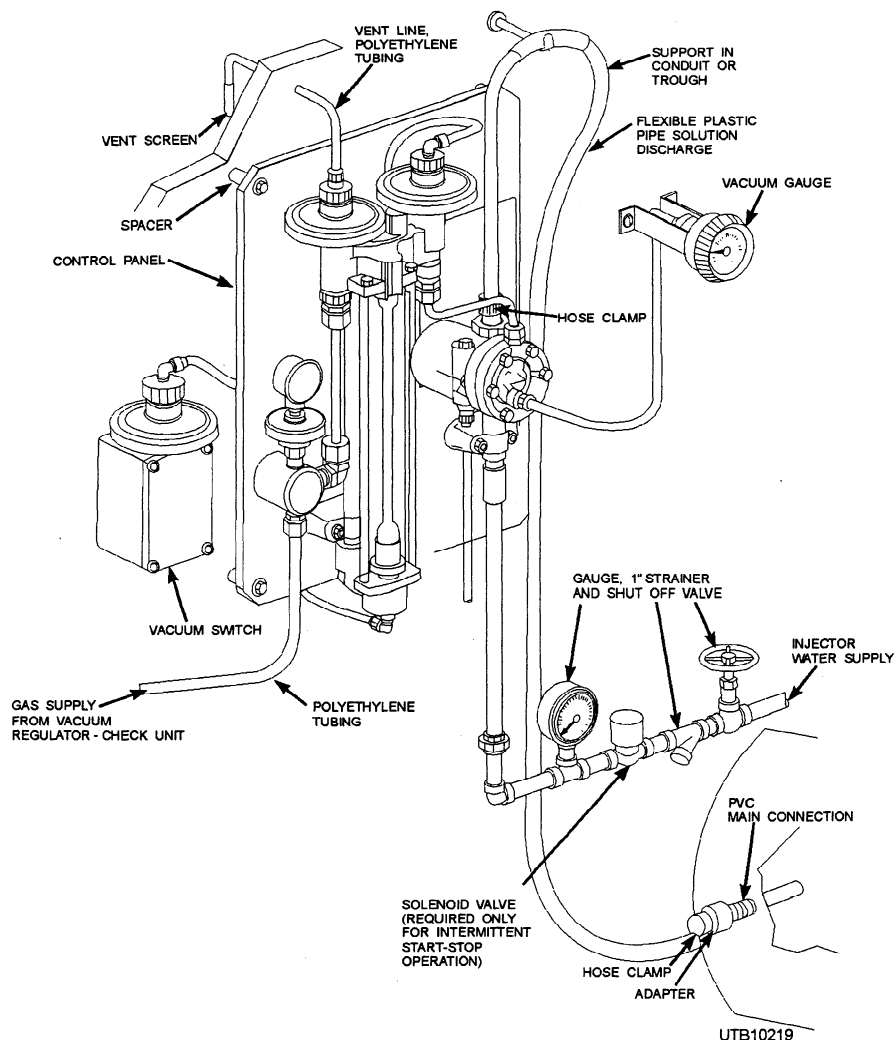


Figure 7-6.—V-Notch Gas Feeder-typical installation, 250 to 500 lb/24 hr.

and the pulsating-type chlorinator. Regardless of the type of chlorinator, make sure that you follow the manufacturer's recommendations and instructions applicable to the operation and maintenance of the equipment.

HYPOCHLORINATORS

Hypochlorinators are solution chemical feeders that introduce chlorine into the water supply as hypochlorite solution. They are usually modified positive displacement piston or diaphragm mechanical pumps. However, hydraulic displacement Hypochlorinators are also used. Fully automatic types are actuated by the pressure differentials produced by orifices, venturis, valves, meters, or similar devices. Hypochlorinators are sometimes used as standby equipment for gas chlorinators. Portable equipment is

also available which may be used for main disinfection or during emergencies. Hypochlorinators can also be used to feed chemicals for scale and corrosion control. Of course, you may have to use various types of Hypochlorinators. As part of this discussion on chlorination equipment, a brief treatment is given on additional types of Hypochlorinators of interest to the Utilitiesman.

The Proportioners Chlor-O-Feeder is a positive displacement diaphragm-type pump with an electrically driven or hydraulically operated head. The electrically driven Proportioners Chlor-O-Feeder is shown in figure 7-9. The capacity of the most popular type, the heavy-duty Midget Chlor-O-Feeder, is 95 gallons of solution in 24 hours.

The motor-driven type of hypochlorinator may be electrically interconnected with the pump motor

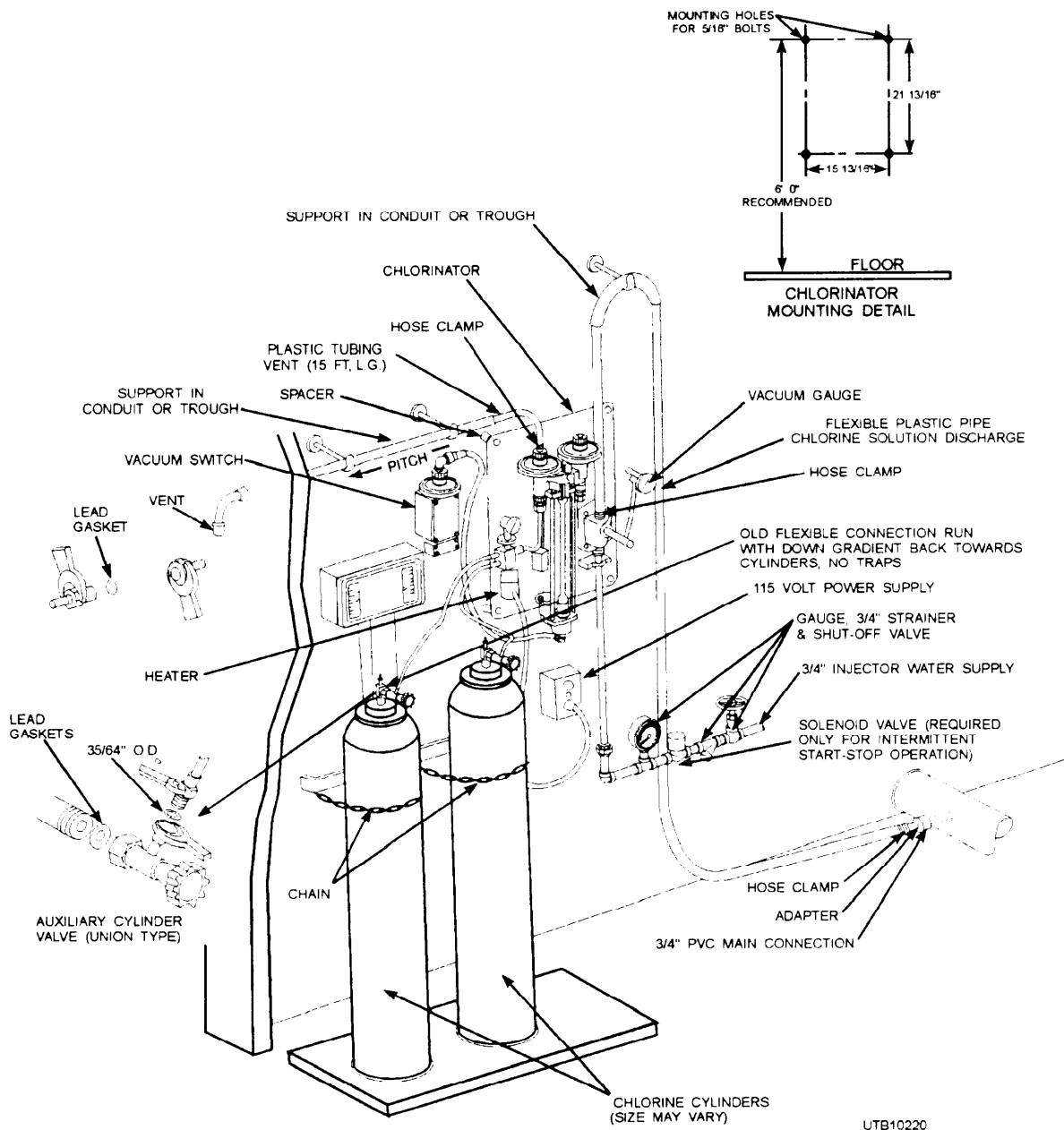


Figure 7-7.—V-Notch Chlorinator—typical installation, 3 to 200 lb/21 hr.

controls for semiautomatic operation (fig. 7-10). The hydraulic type can be synchronized with pump operation by means of a solenoid valve.

Motor-driven types of Hypochlorinators are made fully automatic by use of a secondary electrical control circuit actuated by a switch inserted in a disk or compound-meter gearbox (fig. 7-11). This switch closes momentarily each time a definite volume of water passes through the meter, thus starting the feeder. A timing element in the secondary circuit shuts off the feeder after a predetermined, adjustable number

of feeder strokes. In the hydraulic type, the meter actuates gears in a gearbox, which, in turn, controls operation of a pilot valve in the water or air supply operating the feeder. The dosage rate is controlled by water flow through the meter, thus automatically proportioning the treatment chemical. The opening and closing frequency of the valve determines the frequency of operation of the hypochlorinator.

Other types of Hypochlorinators available include the Model S, manufactured by the Precision Chemical Pump Corporation. The Model S Hypochlorinator is a

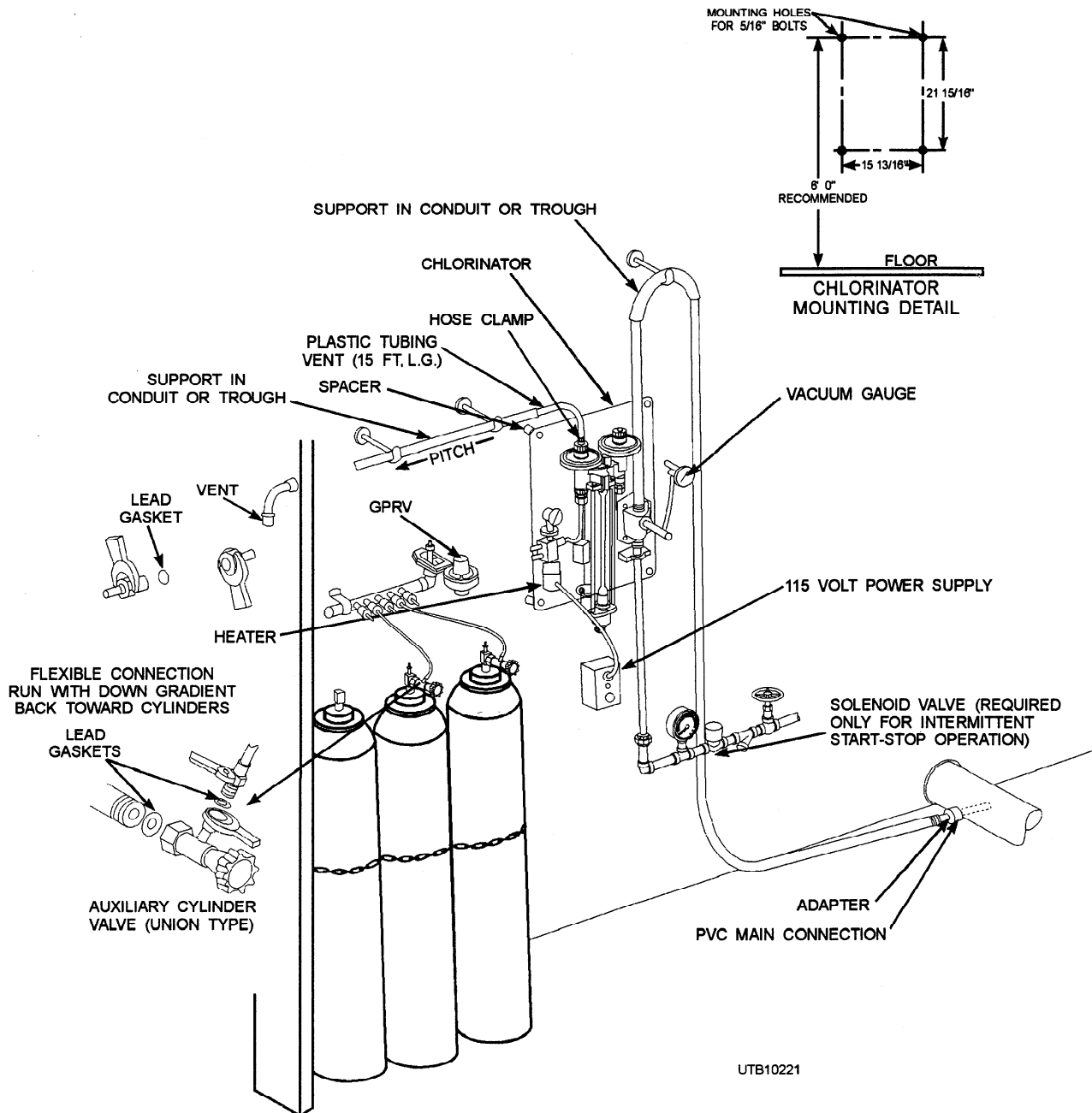


Figure 7-8.—V-Notch Chlorinator-typical installation, 250 to 500 lb/24 hr.

positive displacement diaphragm pump with a manually adjustable feeding capacity of 3 to 60 gallons per day (fig. 7-12). A motor-driven eccentric cam reciprocates the diaphragm, injecting the solution into the main supply. The use of chemically resistant plastic and synthetic rubber in critical parts contributes to its long operating life.

LOCATION OF EQUIPMENT

Chlorination equipment must be properly located with proper ventilation. All gas-chlorinating

equipment and chlorine gas cylinders, filled or empty, should be in a separate room opening only from the outside and should not be in the same room or enclosure with operating equipment, other than equipment required for chlorination. If these conditions do not exist, take up the matter with your supervising petty officer. As we said earlier, a typical chlorinator installation is shown in figure 7-7.

If the chlorination room is not at such an elevation that the floor is level with or above the surrounding ground area, an exhaust fan (positive pressure blower

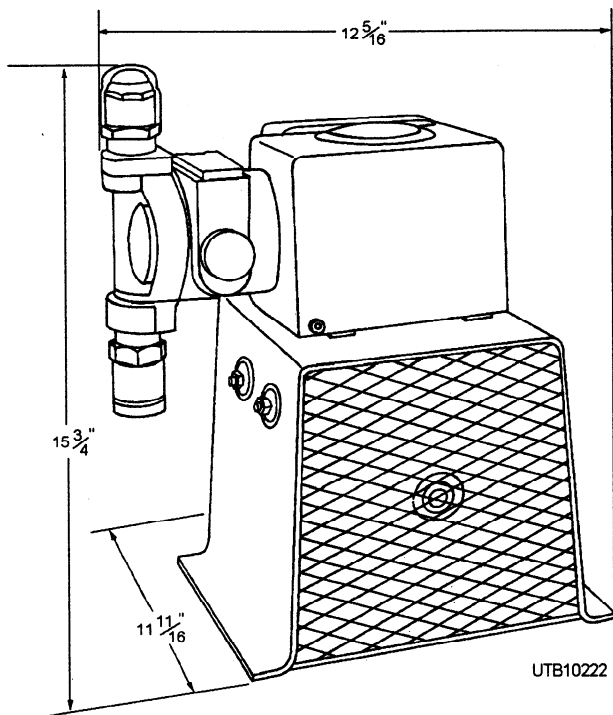


Figure 7-9.—Electrically driven Proportioners Chlor-O-Feeder.

type) should be installed to remove gas or air at the floor level. Mechanical exhaust ventilation is provided at floor level in any case. Doors should open outward, and two-way lighting switches should be provided,

both outside and inside the room. If standard design conditions have not been met, get advice on what to do from your supervising petty officer.

It is normal to put Hypochlorinators in the same room with other equipment, such as pumps, switchboards, meters, and the like. However, because of the corrosiveness of the solutions, it is better to put them in a separate room. If adequate floor drains have not been provided for waste water, spillage, sludge, and washdown water, a 6-inch curbing should be provided around the entire area used for this purpose, whether in a separate room or in the same room with other equipment.

LOCATING LEAKS

Even small leaks can be detected because of the characteristically sharp chlorine odor. When a chlorine odor is noted, authorized personnel should start the ventilating system, put on self-contained oxygen-breathing apparatus or self-generating oxygen-breathing apparatus and locate the leak by holding an open bottle of ammonia water close to pipes, fittings, and valves. Ammonia vapor and chlorine gas form heavy white fumes, thus revealing the point from which chlorine is issuing. If the leak is in a line, shut off the flow of chlorine and repair the leak. If it is in the cylinder head and cannot be stopped by closing the valve, waste the gas from the cylinder outdoors in a good wind or run it into a caustic soda solution.

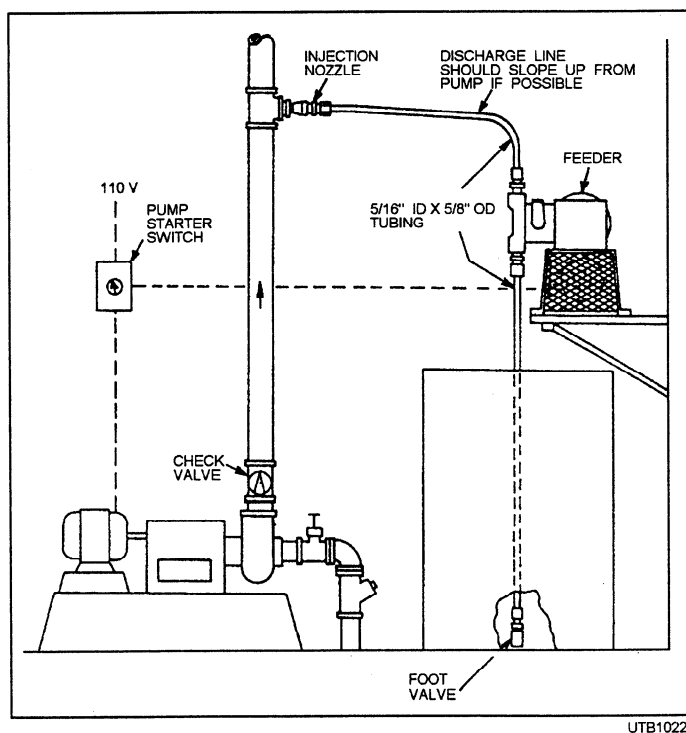


Figure 7-10.—Hypochlorinator arrangement.

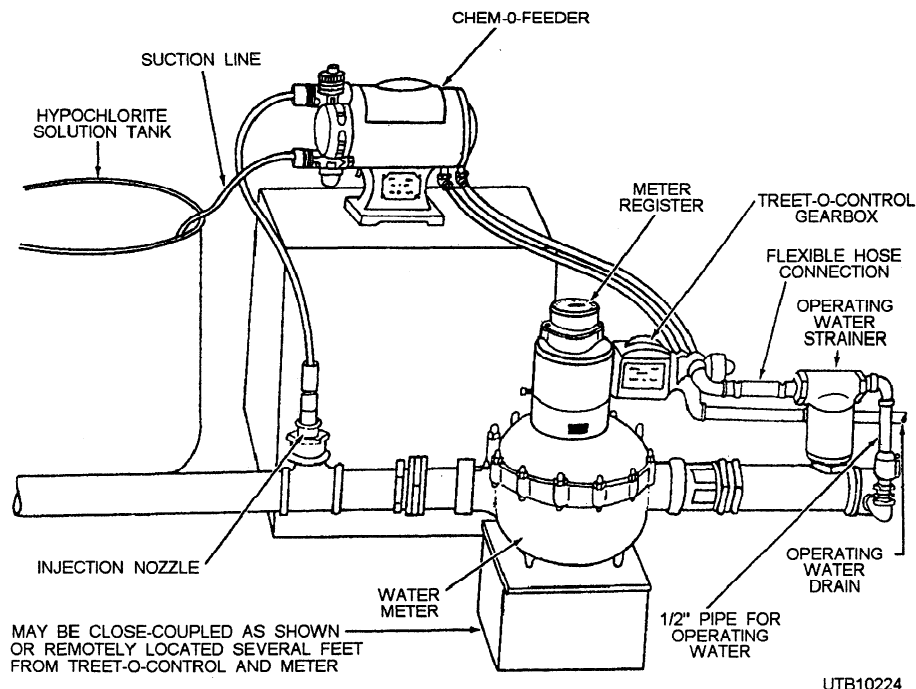


Figure 7-11.—Motor driven hypochlorinator with fully automatic control.

For emergencies, a standby alkali absorption system with a suitable tank should be provided. The alkali should be stored so a solution can be readily prepared. Chlorine should be passed into the solution through a suitable connection properly submerged and weighted to hold it secure. **DO NOT IMMERSE CHLORINE CONTAINERS IN SOLUTION.** Table 7-1 shows a chemical equivalent. Try to use quantities in excess to allow absorption.

HYPOCHLORITES

To prevent accidents caused by the corrosive action of hypochlorite solutions, use vitreous crocks or steel tanks lined with rubber or chlorine-resistant plastic as solution containers. Store calcium hypochlorite in a dry, cool location, and keep the cans

sealed. Wear rubber gloves and protective aprons when preparing and handling hypochlorite solutions.

The liquid CO₂ recarbonization system uses carbon dioxide gas to lower the pH of softened and settled potable water. This unit is designed for operation between -10°F and +3°F that corresponds to pressure of 242.8 psig and 306.8 psig. The pressure vessel is designed for temperatures as low as -20°F and up to 350 psig. The unit comes with or without a vaporizer, depending on the quantity of CO₂ required. (If large amounts of CO₂ are removed, it is possible to cause the temperature to go below -20°F.) Once the unit is installed and in proper operation, it requires little attention. At the beginning and end of each day, the operator should check the pressure and liquid level gauges. The supply valve should be turned off when the unit is not in use. The standard unit is equipped with

Table 7-1.—Recommended Alkaline Solutions for Absorbing Chlorine

Container Capacity	Caustic Soda		Soda Ash		Hydrated Lime	
	100	Water	Water		Water	
lb (net)	lb	gal	lb	gal	lb	gal
100	125	40	300	100	125	125
150	188	60	450	150	183	183
2000	2500	800	6000	2000	2500	2500

AFTER INSTALLATION, IT IS IMPORTANT THAT ALL EXTERNAL SCREWS BE TIGHTENED. THIS INCLUDES THE HEAD MOUNTING SCREWS. BOTH THE SCREWS AND PLASTIC FITTINGS SHOULD ALSO BE CHECKED AND TIGHTENED IF NECESSARY AS PART OF ROUTINE MAINTENANCE PROCEDURES. THIS SHOULD NORMALLY BE DONE AT THE TIME THE OIL IS CHANGED. CAUTION: TIGHTEN PLASTIC FITTINGS BY HAND.

THIS TIGHTENING IS NECESSARY BECAUSE OF THE TENDENCY OF ALL MATERIALS TO "FLOW" UNDER STRESS. THIS RESULTS IN GRADUAL LOOSENING AND MAY LEAD TO LEAKS WHICH ARE APPARENTLY WITHOUT CAUSE.

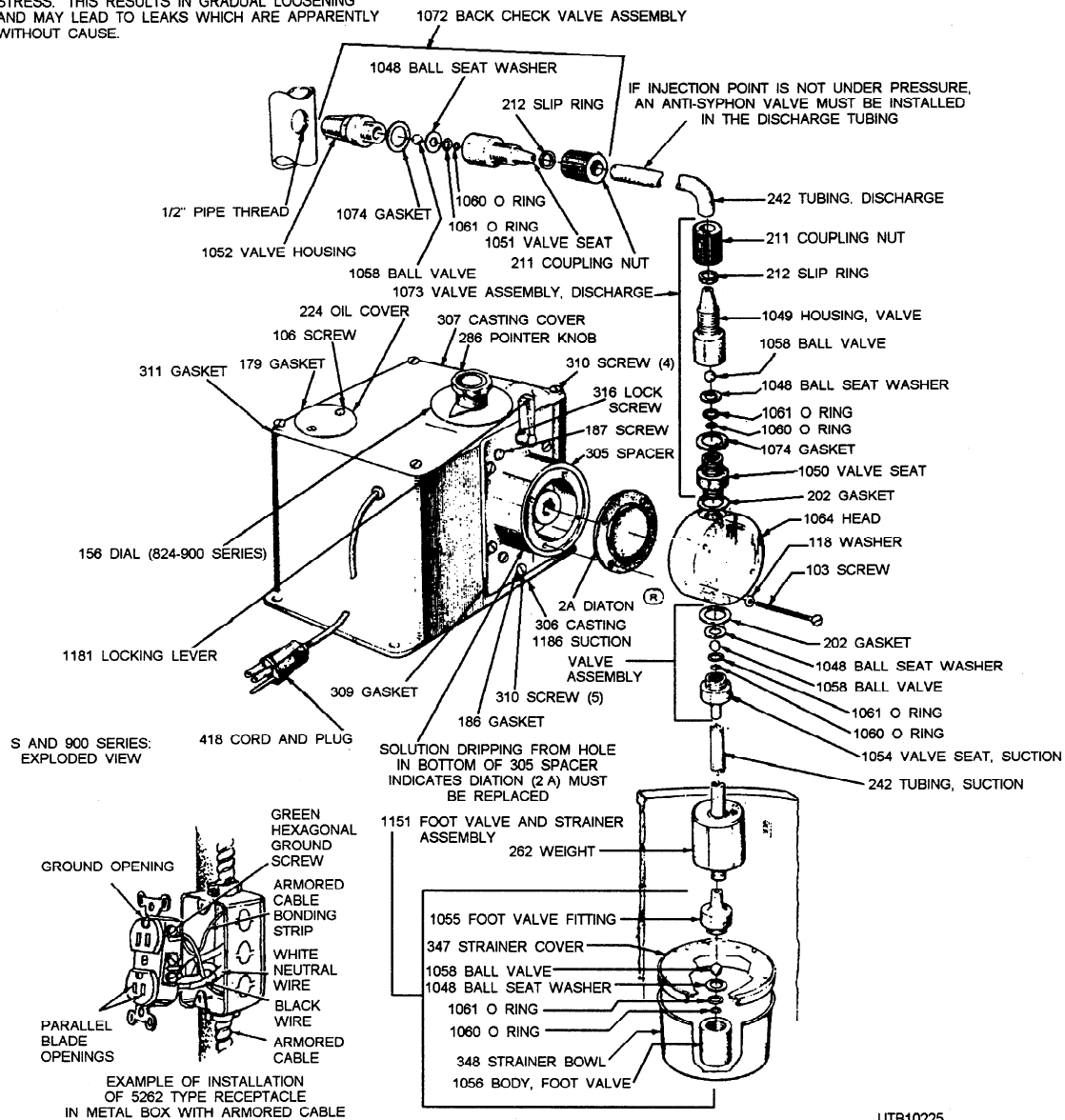


Figure 7-12.—Model S Hypochlorinator.

a pressure vessel, piping and valves, safeties, a refrigeration unit, and a vaporizer. All of these devices require normal maintenance.

AMMONIA

Ammonia fumes are poisonous, but even small concentrations of ammonia are quickly noticeable by

the characteristic odor. Because the gas is extremely soluble, a water spray can pick up ammonia, which has escaped. The same precautions used with chlorine are used in handling ammonia with the following exceptions and additions:

- Because ammonia is lighter than air, install vents at the top of the room.

- Ammonia cylinders do not have fusible plugs because no fusible ammonia-resistant material is available. This presents an acute hazard because an ammonia cylinder filled to the legal limit becomes completely liquid at 145°F, and higher temperature results in a buildup of hydrostatic pressure. Cylinders are tested at 700 psi under Interstate Commerce Commission Regulations.
- Test for leaks in ammonia gas piping with a bottle of diluted muriatic acid. White fumes form as with chlorine.
- Ammonia solution or aqua ammonia can be stored indefinitely, but ammonia gas is created at about 80°F if the container is open. Store it in a cool place and keep the container tightly plugged. Dilute with cool water to 15 percent ammonia content before feeding. Keep the room housing the feeder well ventilated.

SULFUR DIOXIDE

Precautions in storing and handling chlorine also apply to sulfur dioxide (SO₂). Leaks are located with a bottle of ammonia water.

- Q8. Chlorination equipment can be classified by type, depending on what factor?*
- Q9. What type of chlorinator, in most applications, is used as emergency equipment?*
- Q10. When deciding on a location for chlorination equipment, what factor should be the primary safety concern?*
- Q11. What chemical solution is used to detect chlorine leaks?*
- Q12. If a leak develops on a chlorine cylinder that can not be stopped, you should take what action?*

WATER TREATMENT QUALITY CONTROL

LEARNING OBJECTIVE: *Identify material, equipment, and procedures required to perform water treatment control effectively.*

Frequent chemical analyses and bacteriological examinations of raw and treated water are required to determine and control treatment to ensure a safe, potable water. Chemical analyses will determine proper water treatment and the safety of the water in respect to chemical content. Bacteriological

examinations will determine the necessity for disinfection, as well as the safety of the water, following treatment in terms of bacteria content.

You may be called upon to collect samples of water for chemical analysis and bacteriological examination. You may also have to make various types of treatment control tests. (See appendix I). This information will aid you in performing these duties. Safety precautions to be observed by personnel engaged in laboratory work are also covered.

SAMPLING METHODS

The collection of samples for testing for quality control and safety is an important function, because, unless the water sample is representative and uncontaminated, test results will not indicate the actual condition of the water supply. Sample containers should be of materials that will not contaminate the sample and, before use, should be cleaned thoroughly with a detergent and freshwater rinse to remove all surface dirt. Chemically resistant glass is a suitable material for all sample containers, and polyethylene may be used for samples for chemical analyses. The size of the sample container used will depend upon the amount of water needed for a test.

To make certain that representative, uncontaminated samples are obtained, you must observe normal precautions against accidental contamination. Sample containers and caps should always be rinsed well with the water to be tested. Direct hand contact with the mouth of the container, or with the cap, is to be avoided. Take samples with a minimum of splashing.

CHEMICAL ANALYSIS SAMPLES

When collecting samples for chemical analysis, you will find a gallon of water usually enough to determine the mineral content. To obtain accurate test results, flush the sampling lines thoroughly. The bottles should be rinsed out several times with the water to be collected. Procedures for obtaining samples from water supplies for chemical analysis are given below. These procedures should be carefully followed.

Wells

To obtain a representative sample from a well, pump the well until the normal drawdown is reached. Rinse the chemically cleaned sample container and cap

several times with the water to be tested and then fill with a minimum of splashing.

Surface Supplies

When sampling surface supplies, fill chemically cleaned raw water sample containers with water from the pump discharge ONLY after the pump has operated long enough to flush the discharge line. Take the sample from the pond, the lake, or the stream at the intake depth and location with a submerged sampler. Submerged samplers are equipped with automatic or manual valve systems that permit the collection of water at the desired depth.

Treatment Plants

Take samples inside a treatment plant from channels, pipe taps, or other points where good mixing is obtained. At some Navy installations, special sample taps are provided for this purpose.

Distribution System Taps

In the case of taps on a distribution system, let the tap run long enough to draw water from the main before taking samples.

BACTERIOLOGICAL EXAMINATION SAMPLES

In obtaining samples for bacteriological examination, avoid contaminating the bottle, stopper, or sample, because contamination often causes a potable water supply to be reported as nonpotable. Follow these precautions and get valid results.

Sample Containers

Use only clean, sterilized bottles furnished by the medical department of the installation or another qualified laboratory. If bottles are not available from these sources, sterilization may be carried out in emergencies. The tops and necks of sample bottles with glass closures should be covered with metal foil, rubberized cloth, or heavy impermeable paper or milk bottle cover tops before sterilization. Before sterilizing the sample bottle to be used for a chlorinated water sample, place 0.02 to 0.05 gram of thiosulfate, powdered or in solution, into each bottle to neutralize the chlorine residual in the sample. Keep the sterilization temperature under 393°F (200°C) to avoid decomposition of the thiosulfate.

Sampling from a Tap

When sampling from a tap, heat the outlet with an alcohol or gasoline torch for a few seconds to destroy any contaminating material that may be on the tip of the faucet. Occasionally, extra samples may be collected without flaming the faucet to determine whether certain faucet outlets are contaminated.

Flush the tap long enough to draw water from the main. Never use a rubber hose or another temporary attachment when drawing a sample for bacteriological examination from the tap.

Next, without removing the protective cover, remove the bottle stopper and hold both the cover and the stopper in one hand. Do not touch the bottle mouth or the sides of the stopper. Fill the bottle without rinsing (to avoid loss of thiosulfate). Replace the cap and fasten the protective covering carefully.

Sampling from Lakes, Ponds, Streams, and Pools

When collecting samples from standing water, remove the stopper as above, and plunge the bottle, mouth down, and hold it at about a 45° angle at least 3 inches below the surface. Tilt the bottle and allow air to escape and fill, moving it in a direction away from the hand holding it, so water that has touched the hand does not enter the bottle. Discard a quarter of the water and replace the stopper.

When collecting a sample from lakes or ponds, take the water 25 feet or more from the shore (from boat or pier) and preferably in water at least 4 feet deep. Do not collect the sample at the shore.

A stream sample should be collected where the water is flowing, not from still areas. In a meandering stream, collect the sample where flow velocity is normal. Use the procedure given above for standing water samples.

When collecting water from a swimming pool, take the water from the side of the pool near the deepest part. Sample the pool while it is in use, preferably during the heaviest bathing load. Use the bottle containing thiosulfate. Fill according to the sampling procedure given above for standing water.

Q13. To ensure accurate results of water testing when collecting water samples, you should take all precautions to ensure that the samples are not in what condition?

Q14. To obtain a proper sample from a well, you should take what action first?

Q15. When taking samples from a standing water supply, you take the samples from how far below the surface and at what angle?

TREATMENT CONTROL TEST PROCEDURES

LEARNING OBJECTIVE: *Understand procedures and analysis for different types of water tests.*

Various analyses of water must be performed by trained chemists or skilled laboratory technicians. As a Utilitiesman, however, you must be able to perform various types of treatment control tests. These tests are used during treatment to ensure proper operation and the output of safe water of acceptable quality. We will describe the procedures to follow in carrying out a number of treatment processes, such as chlorination, corrosion control, and clarification.

Before proceeding, note that certain tests which we will cover are based on the simple principle of adding a chemical to the sample that forms a color with the substance to be measured and matching the treated sample with color standards containing known amounts of the substance. There are several colorimeter sets available commercially which vary slightly in use and operation. For that reason, make a careful study of the manufacturer's instructions before using such equipment. Other tests are performed by titration or by special instruments. "Titration" means finding out how much of a substance is in a given solution by measuring how much of another substance or reagent has to be added to the given solution to produce a given reaction.

Various reagents required for the tests discussed below are available from a number of manufacturers and laboratory supply houses. Some of these reagents require special preparation and handling before test use. This is customarily the responsibility of the laboratory technician, since, in some cases, the preparation of reagents requires a thorough knowledge of the chemical procedures. For complete information on the preparation of reagents, refer to the manufacturer's instructions or consult your supervising petty officer.

CHLORINE RESIDUALS

Two tests are frequently used in testing water for chlorine residuals. They are the orthotolidine test and

the orthotolidine-arsenite (OTA) test. Each of these tests is discussed separately below.

Orthotolidine Test

Chlorine residuals can be measured easily by using a commercial comparator and orthotolidine reagents.

EQUIPMENT.—Either a disk or slide comparator may be used in performing the orthotolidine test. A disk comparator is shown in figure 7-13. This comparator consists of a standard color disk and two sample tubes. Water to be tested is placed in both tubes. Reagent is added to one and the resulting color matched with the disk. The other tube is placed behind the disk to eliminate any color error that might be caused by turbidity in the test sample.

A slide comparator, also referred to as a block comparator, is shown in figure 7-14. This comparator consists of standard color ampoules for more accurate color matching. The other two sample tubes are used as compensators and are placed behind the color ampoules.

— only reagent used is a standard orthotolidine solution.

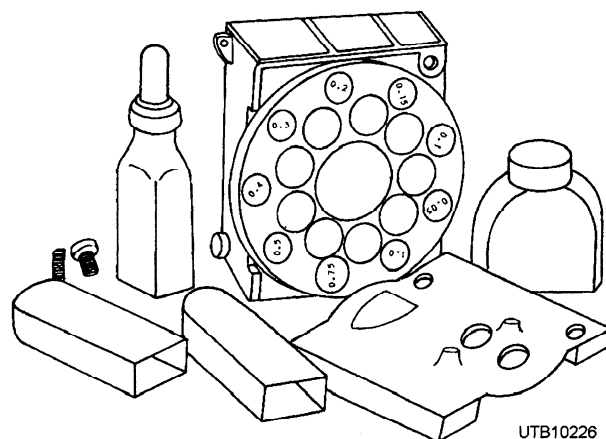


Figure 7-13.—Disk comparator with the front removed show construction.

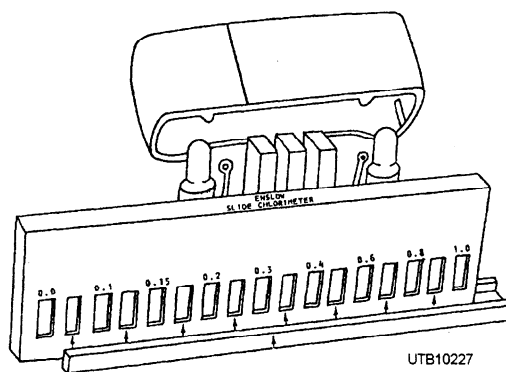


Figure 7-14.—Slide comparator for chlorine residual test.

manufacturer of the comparator used. The general procedure consists of four steps as follows:

1. Fill the tubes to the mark with the water.
2. Place the compensating tube or tubes behind the color standard
3. Add 10 to 15 drops of orthotolidine to the test sample; mix and let stand for 5 minutes. Keep the sample in the dark during the 5-minute color development to reduce false color caused by manganese and nitrate compounds. If a blue color appears after 5 minutes, add more orthotolidine. If water is colder than 50°F, warm it by holding the tube in your hand. Place the sample tube in the comparator and match the color, holding the comparator toward the light, preferably daylight.
4. Select the standard color nearest that of the sample and read the residual. If color appears to be halfway between two standards, report the residual as an average of two standards. Thus, if color appears halfway between 0.3 and 0.4 ppm, report the residual as 0.35 ppm.

Note that the orthotolidine test is not wholly accurate because the false color introduced by nitrates and manganese compounds cannot be entirely eliminated. However, the orthotolidine-arsenite test, described in the following section, does eliminate the false color error completely.

Orthotolidine-Arsenite Test

The orthotolidine-arsenite (OTA) test permits the measurement of relative amounts of total residual chlorine, free available chlorine, and combined available chlorine. This test has some limitations. Samples containing a high proportion of combined available chlorine may indicate more free available chlorine than is actually present, while samples containing a low proportion of combined available chlorine may indicate less free available chlorine than is actually present. Precise results depend on strict adherence to the conditions of the test. The conditions are the time intervals between the addition of reagents and the relative concentration of free available chlorine and combined available chlorine in the sample and the temperature of the water. The temperature of the sample under examination should never be above 68°F (20°C). The precision of the test increases with decreasing temperature.

EQUIPMENT.—You will need a color and turbidity-compensating residual chlorine comparator with commercial permanent standards.

REAGENTS.—The reagents used are orthotolidine (OT) and arsenite (A).

TEST PROCEDURES.—In testing, follow the procedures outlined below.

1. Label three comparator cells A, B, and OT.
2. Use 0.05 milliliter (ml) of OT reagent for each ml of the sample taken. For example, use 0.5 ml of OT reagent for a 10-ml sample and 0.75 ml for a 15-ml sample. Use the same volume of a reagent as is specified above for OT reagent.
3. To tube A, first add OT reagent, then add a measured volume of the water sample; mix quickly.
4. Within 5 seconds, add arsenite reagent; mix quickly.
5. Compare with color standards as rapidly as possible.
6. Record the result; the value obtained represents free available chlorine and interfering colors.
7. To tube B, first add arsenite reagent; then add a measured volume of water sample; mix quickly.
8. Immediately add OT reagent; mix quickly.
9. Compare with color standards as rapidly as possible.
10. Record the results as the B-1 value.
11. Compare the color standards again in exactly 5 minutes and record the results as the B-2 value; these values represent the interfering colors present in the immediate reading B-1 and in the 5-minute reading B-2.
12. To tube OT, containing orthotolidine reagent, add a measured volume of the water sample.
13. Mix quickly and compare with color standards in exactly 5 minutes.
14. Record the result; the value obtained represents the total residual chlorine present and total interfering colors.

CALCULATION OF RESULTS.—In calculating results of the orthotolidine-arsenite (OTA) test, follow the procedure below.

Total residual chlorine. From the value of OT, subtract the value of B-2. The difference equals total residual chlorine.

$$(\text{OT}) - (\text{B-2}) = \text{total residual chlorine}$$

Free available chlorine. From the value of A, subtract the value of B-1. The difference equals free

$$(OT) - (B-2) = \text{total residual chlorine}$$

Free available chlorine. From the value of A, subtract the value of B-1. The difference equals free available chlorine.

$$(A) - (B-1) = \text{free available chlorine.}$$

Combined available chlorine. From the value of total residual chlorine, subtract the value of free available chlorine. The difference represents combined available chlorine.

$$(\text{Total residual chlorine}) - (\text{free available chlorine}) = \text{combined available chlorine.}$$

pH TEST

The pH test measures the strength of acid or alkali in water. It is reported on a scale that ranges from 0 to 14. A pH reading of 7 is neutral (in a technical sense), values below 7 are acidic, and those above 7 are alkaline. Color comparators can be used to find pH by methods similar to those for determining chlorine residuals. The determination of pH in three simple operations is shown in figure 7-15.

Indicators

Many pH indicators are available, each with a limited range. The indicators used for treated water supplies are as follows:

pH RANGE	INDICATOR
5.2 to 6.8	Chlorphenol red
6.0 to 7.6	Bromthymol blue
6.8 to 8.4	Phenol red
7.2 to 8.8	Cresol red

The correct standards must be used with each indicator.

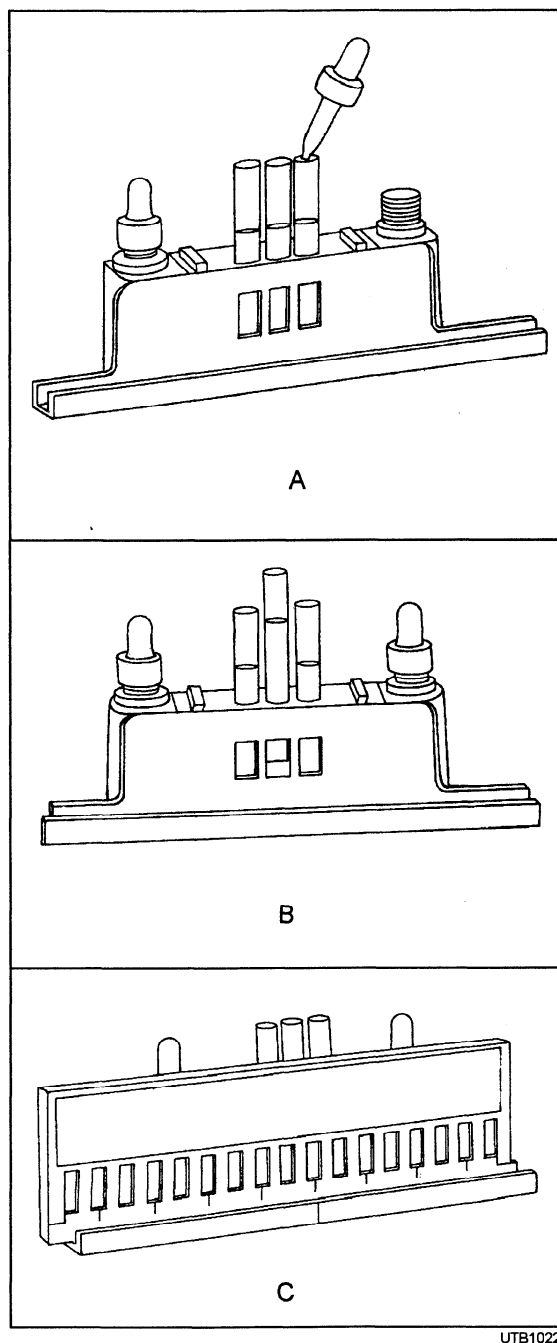
Procedures

In making the pH test, proceed as follows:

1. Fill the tubes to the mark with the sample.
2. Add the indicator to one tube in the amount specified by the manufacturer.

NOTE: Usually 0.5 ml (10 drops) for a 10-ml sample tube and proportionately more for larger tubes.

3. Mix and place the tube in the comparator.



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Figure 7-15.—pH determinations in three steps: A. Add reagent; B. Remove tube; and C. Compare colors.

4. Match for color and read the pH directly.

5. If the color matches the standard at either the upper or the lower end of the range of the indicator, repeat the test with the next higher or lower indicator. For instance, if bromthymol blue is used and the sample matches the blue color of the 7.6 standard, the pH is 7.6 or higher. Therefore, use a phenol red indicator to check this value.

SALINITY TESTS

At times you may be assigned to perform salinity tests with a field water, quality control kit. These tests serve to identify mineral characteristics of the water.

The quality control kit provides the necessary materials and equipment for the tests. Two bottles of reagents, one small and one large, are included. As the solution is used up during the test, the small bottle is refilled from the larger bottle. The test bottles have two marks—the lower one at 50-ml capacity and the upper one at 100-ml capacity. The test solutions are measured with pipettes. These pipettes deliver a total of 1 ml from the upper graduation mark and are calibrated in 1/10-ml divisions. Each pipette is to be used only for the test for which it is marked in the pipette case and is to be returned directly to its place when the test is completed.

Four types of salinity tests, which you may perform, are as follows—the alkalinity test, the hardness test, the chloride test, and the sulfate test. Each of these tests is discussed in subsections below.

The Alkalinity Test

Alkalinity of water results from the presence of bicarbonate, carbonate, hydroxides of calcium, magnesium, sodium, and other minerals. The term *alkalinity* has little or no relation to the pH of the water but refers to the acid-neutralizing capacity of the water. In other words, alkalinity of water refers to the amount of various alkalies in the water that are capable of neutralizing acids. One method of determining the alkalinity of a water sample is by titration with standard sulfuric acid first to the phenolphthalein (PT) end point, and then to the methyl purple or methyl orange end point. Although methyl orange is the “standard indicator,” methyl purple is much easier for the average operator to use because its color change is easier to see, and the results obtained with it are good enough for almost all uses.

REAGENTS—The reagents used in testing the alkalinity of water are as follows:

Phenolphthalein (PT) Indicator Solution
Methyl Purple Indicator Solution
Methyl Orange Indicator Solution
Standard Sulfuric Acid (N/50)

PROCEDURE WITH METHYL PURPLE—In determining the alkalinity of water with methyl purple, use the following procedure:

1. Measure 100 ml of the clear sample (filtered if necessary) into an evaporating dish or Erlenmeyer flask.

2. Add 4 drops of phenolphthalein indicator solution. If a pink or red color develops, phenolphthalein alkalinity (alkalinity fraction contributed by hydroxide and half of carbonate) is present.

3. Fill the burette with acid and add to the sample slowly just until the pink color disappears.

4. Record the ml of acid used.

5. Now, add 2 to 4 drops of methyl purple indicator.

6. Continue titration, adding the acid in 0.5-ml portions until a greenish tint appears where the acid hits the sample. Then continue the addition more slowly, about 3 drops at a time. The color will change from green to gray and then to purple. The appearance of the purple tint marks the end point.

7. Record the total ml of acid required to reach this end point. This includes the ml of acid used in the phenolphthalein alkalinity titration and that used in the methyl purple titration.

PROCEDURE WITH METHYL ORANGE—In determining the alkalinity of water with methyl orange, follow the procedure given below.

1. Measure 100 ml of the clear sample (filtered if necessary) into an evaporating dish or Erlenmeyer flask.

NOTE: If an evaporating dish is used to get a white background for better color observation, the sample must be stirred with a stirring rod during addition of the standard acid.

2. Add 4 drops of phenolphthalein indicator solution. If a pink or red color develops, phenolphthalein alkalinity (alkalinity fraction contributed by hydroxide and half of carbonate) is present.

3. Fill the burette with the acid and add to the sample slowly just until the pink color disappears.

4. Record the ml of acid used.

5. Now, add 2 to 4 drops of methyl orange indicator.

6. Continue titration, adding the acid in 0.5-ml portions until the reddish color that appears where the acid hits the sample begins to persist. Then continue the addition more slowly, about 3 drops at a time, until the first pinkish tinge is seen throughout the sample. This is the end point.

7. Record the total ml of acid required to reach this end point. This includes the ml consumed in the phenolphthalein alkalinity titration and that consumed in the methyl orange titration.

CALCULATIONS—The phenolphthalein (PT) alkalinity is calculated as ppm of calcium carbonate by multiplying the ml of acid used in the phenolphthalein titration by 20.

$$\begin{aligned} &\text{ppm PT alkalinity as calcium carbonate} \\ &= \text{ml of acid used in step} \times 20 \end{aligned}$$

The total alkalinity, as ppm of calcium carbonate, is found by multiplying the total number of ml of acid used (Step 6 above) by 20. This applies to both the methyl orange and the methyl purple procedures.

$$\begin{aligned} &\text{ppm total alkalinity as calcium carbonate} \\ &= \text{total ml acid used} \times 20 \end{aligned}$$

The Hardness Test

The titration method for determining water hardness is vastly superior to the old soap test that is slow, tedious, and often may give misleading results. The procedure is based on the fact that when a sample of water is titrated with a solution of EDTA (sodium ethylene, diamine tetraacetate), calcium and magnesium react with the EDTA to form soluble compounds in which calcium and magnesium are tied up so firmly that they cannot react with other materials. Standard EDTA solution is added to a water sample and the end point is detected by an indicator that is red in the presence of calcium and magnesium ions and blue in their absence. A total hardness test set (EDTA) is shown in figure 7-16.

REAGENTS—The following reagents are used in testing for water hardness:

- EDTA solution
- Hardness indicator powder
- Hardness buffer
- Hardness reagent

PROCEDURES—In determining water hardness, here is the procedure to follow.

1. Place a 50-ml sample in a 250-ml Erlenmeyer flask.
2. Add 1 dipper of hardness indicator powder.
3. Add 0.50 ml of hardness buffer to hold the pH at around 10. The color of the mixture will be red if any hardness is present.
4. Add the hardness reagent from a burette until the red color just disappears, giving way to a pure blue.

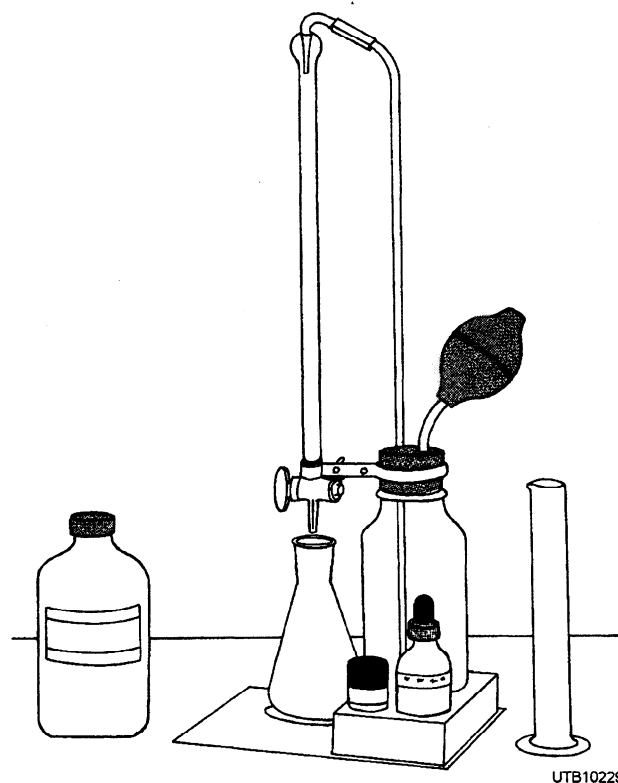


Figure 7-16.—Total hardness test set (EDTA).

CALCULATIONS—The burette reading in ml is multiplied by 20 to give the total hardness.

$$\begin{aligned} &\text{ppm total hardness as calcium carbonate} \\ &= \text{ml burette reading} \times 20 \end{aligned}$$

The Chloride Test

The purpose of the chloride test is to measure the amount of chloride ions and common salt (NaCl) in water. This test also indicates the presence of possible sewage pollution.

REAGENTS—The reagents used in making the chloride tests are as follows:

- Phenolphthalein Indicator
- Methyl Orange Indicator
- Potassium Chromate
- Silver Nitrate Standard
- Aluminum Hydroxide
- Sulfuric Acid (1 to 3)

PROCEDURES—When making a chloride test, follow the procedure below.

1. Pipette 50 ml of the sample into a 6-inch white porcelain evaporation dish.

2. Place the same quantity of distilled water into a second dish for color comparison.

3. To both dishes, add 1 ml of potassium chromate. Titrate the dish with the sample. Add standard silver nitrate solution (2.4 grams per liter) from a burette, a few drops at a time, with constant stirring until the first permanent reddish coloration appears. (This can be determined by comparison with the distilled water blank.) Record the ml of silver nitrate used.

4. If more than 7 or 8 ml of silver nitrate solution is required, the entire procedure should be repeated by using a smaller sample diluted to 50 ml with distilled water.

CALCULATIONS—When making calculations for chloride, use the formula below.

$$\text{Ppm chloride (C l)} = \frac{\text{ml of AgNO}_3 \text{ used} - 0.2 \times 500}{\text{ml of sample}}$$

Three precautions to bear in mind are as follows:

1. If the sample is highly colored, it should be decolorized by shaking with washed aluminum hydroxide and filtering.

2. If the sample is highly acid, add 10 percent sodium carbonate solution until it is slightly alkaline to methyl orange.

3. If the sample is highly alkaline, add diluted sulfuric acid until it is just acid to phenolphthalein.

The Sulfate Test

The sulfate test determines whether sulfates are present in sufficient quantities in water to cause undesirable physiological effects because sulfates can cause diarrhea in human beings. In the sulfate test, the sulfate value is found by trial, as the test merely determines approximate values. For this reason, you may have to repeat the test several times. The test is begun by testing for sulfates at 100 ppm as follows:

1. Fill a clean test bottle to the 100-ml mark with the water sample.

2. Add 1 ml of barium chloride solution to the same and use a barium chloride pipette. Shake intermittently for 10 minutes.

3. Tear a piece of filter paper into small pieces and place the pieces in the solution.

4. Shake the bottle for 5 minutes or until the paper becomes fluffy and gelatinous.

5. Place a funnel and filter paper in a second bottle.

6. Filter about 25 ml of the sample into the second bottle. Rinse the second bottle with this amount of filtrate, and discard the filtrate. Replace the funnel and continue filtration until 50 ml of filtrate is collected.

7. Add 1 ml of barium chloride solution to the filtrate with the barium chloride pipette. Shake for 5 seconds, and observe immediately for a precipitate or clear solution.

If a clear solution is obtained, record the sulfates as less than 100 ppm. As an immediate precipitate or milky solution indicates the sulfates are greater than 100 ppm, a new sample must be tested for 200-ppm sulfate. For each additional 100-ppm sulfate test required, add 1 ml of barium chloride solution. Therefore, 3 ml of barium chloride solution must be added to test for 300-ppm sulfate. However, the 1 ml of barium chloride solution added after filtration is not changed.

If a clear solution is obtained, the sulfates are less than the ppm for which they were tested, and the value is recorded as being between the values of the last preceding tests. A precipitate or milky solution requires that a new sample of the water be tested for the next higher value.

COLOR TEST

Color in water is due to various materials in solution, although suspended turbidity occasionally adds an apparent color to water that may add to or disguise the true color. In water with low turbidity, the apparent color corresponds closely to the true color. However, if turbidity is high, the apparent color may be misleading. To determine the true color, first filter the water through clean white filter paper before it is compared with the standards. Because the filter paper often removes some true color from the first portion of the sample, discard the first 100-ml which pass through the filter and use the next portion for the color comparison. Make the color determination by matching the sample color with color standards in a color comparator.

TASTE, ODOR, AND THRESHOLD ODOR TEST

Unless the water has a definite taste (sweet, sour, salty, or bitter), the sensation produced upon the observer is generally due to the presence of odor, rather than taste. These two senses work in unison. Sulfur water, for instance, apparently tastes “terrible” when it is really only its rotten egg odor that is registering on our senses.

In measured observations, odor determinations are much to be preferred to taste determinations. There is no method for measuring tastes quantitatively.

The threshold odor test is the most widely used method of determining odor levels. It consists of comparing different dilutions of the sample (diluted with odor-free water) to an odor-free standard. The dilution at which the odor can just be detected is called the threshold point. The odor at the threshold point is expressed quantitatively by the threshold number. This is simply the number of times the odor-bearing sample is diluted with odor-free water. For example, if odor-bearing water requires dilution to ten times its volume with odor-free water to make the odor just perceptible, its threshold number will be 10. A more concentrated odor-bearing water will require dilution to 100 times its volume to make the odor just perceptible; its threshold number will be 100. Here are some basic principles of measuring odor values consistently.

1. Some practice with the test is desirable to develop consistent threshold sensitivity. The consistency can be developed readily in most individuals. An acute sense of smell is not essential.

2. An adequate supply of freshly prepared odor-free water must be available before starting the test.

3. All glass must be clean and free of odor. Rinse all glassware several times with odor-free water before each test and between dilutions.

4. Tests should be run in a room free from foreign odors. Odors caused by fresh paint, volatile solvents, tobacco smoke, food, and the like, will decrease the accuracy of the observations.

5. Each dilution should be compared with the odorless standard to check judgment and minimize reliance on odor memory.

Equipment

The following items of equipment are needed to carry out the threshold odor test:

- Six 500-ml Erlenmeyer flasks with ground glass stoppers
- Two thermometers (0°C-110°C)
- One 250-ml graduated cylinder
- One 100-ml graduated cylinder
- One 50-ml graduated cylinder
- One 25-ml graduated cylinder
- One 10-ml Mohr pipette

- One large hot plate
- One odor-free water generator (fig. 7-17)
- Several large flasks for collecting and heating odor-free water

PROCEDURES

In carrying out the threshold test, determine first the approximate range of the threshold odor number. Carefully follow these steps.

1. Add 250-ml, 63-ml, 16-ml, and 4-ml portions of the odor-bearing water to separate 500ml glass-stoppered Erlenmeyer flasks.

2. Dilute the last three to 250 ml with odor-free water.

3. Add 250 ml of odor-free water to another flask that will be the reference for comparison.

4. Heat the flasks to 140°F (60°C) on a hot plate.

5. Shake the odor-free flask, remove the stopper, and sniff the vapors.

6. Do the same with the flask containing the least amount of odor-bearing water and observe by comparison whether it contains an odor, and, if so, what type of odor. (See table 7-2.)

7. Repeat steps 5 and 6 and use the sample containing the next higher concentration of the water sample.

8. Continue the process until all dilutions have been observed.

9. Record which flasks contain an odor and which do not. Experience will enable an operator to estimate the

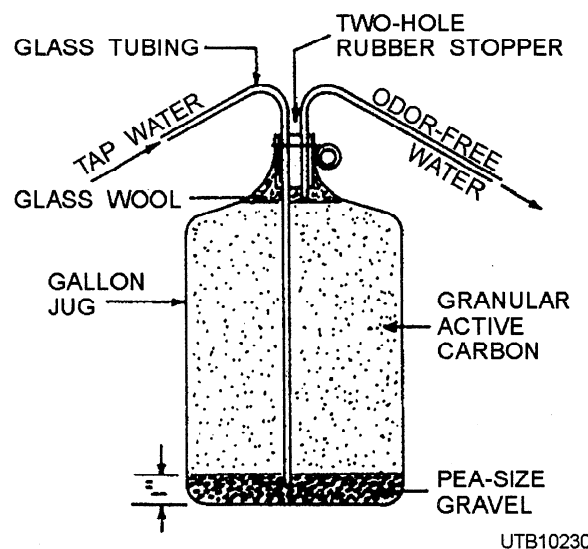


Figure 7-17.—Odor-free water generator.

Table 7-2.—Types of Odors Commonly Found in Water Supplies

Aromatic (spicy)	Disagreeable
Cucumber	Fishy
Balsamic (flowerly)	Pigpen
Geranium	Septic (sewage)
Nasturtium	Earthly
Sweetish	Peaty
Violet	Grassy
Chemical	Musty
Chlorinous	Moldy
Hydrocarbon (gasoline)	Vegetable
Medicinal	
Sulfuretted (rotten egg)	

approximate odor range by sniffing the undiluted sample, thereby eliminating the preliminary test.

10. Based on the results obtained in the preliminary test, prepare a set of dilutions and use the amount of the sample diluted with odor-free water in the range corresponding to the lowest dilution in which the odor was detected. For example, if odor was detected in the 63-ml dilution, but not in the 16-ml dilution, use series II in table 7-3.

11. Repeat steps 5 through 9. The threshold number is read from table 7-4.

JAR TEST (COAGULATION)

The jar test is a reliable method for determining the proper chemical dosages and conditions for coagulation of water to remove color and turbidity.

The type of chemicals that should be used for coagulating raw water can be determined by using the results from jar tests, plant tests, or by using the data shown in table 7-5. Theoretically table 7-5 is correct; however, these values can be misleading when applied to some types of raw water. The chemical content of water may have a considerable influence on the optimum pH range for the various coagulants. For example, coagulation with ferrous sulfate is usually best accomplished at relatively high pH values in the alkaline zone. With soft, colored waters, ferric coagulants may sometimes be used with considerable success at pH values of 4.0 or less. Because of this wide variation in the optimum pH range of coagulants (caused by individual characteristics of the raw water), the coagulant dosage and the optimum zone for floc formation should be determined by jar tests, rather than just relying on table 7-5.

Table 7-3.—Dilution Series for Determining the Threshold Odor Number

Series	I	II	III
Amount of sample diluted to 250 ml	250	63	16
	177	44	11
	125	31	8
	88	22	5.5
	63	16	4

The jar test is the most common method of determining proper coagulant dosages. When there is a question as to which chemical should be used as a coagulant, it is often necessary to run more than one series of jar tests. Different coagulant chemicals and pH ranges should be used to determine which one produces the most satisfactory results at the lowest cost. The step-by-step procedures for a jar test are as follows:

1. Prepare a standard solution of each coagulant selected for trial by adding 10 grams of coagulant to 1 liter of distilled water.

2. Correct the pH of a sample of raw water to within the optimum range for the coagulant being tested (only if the pH is to be adjusted to the same extent in actual plant operation). Divide the raw water into six 1-liter samples.

Table 7-4.—Threshold Odor Numbers

Amount of sample diluted to 250 ml	Threshold odor Number
250	1
177	1.4
125	2
88	2.8
63	4
44	5.6
31	8
22	11
16	16
11	22
8	32
5.5	45
4	64

Table 7-5.—Optimum pH Ranges for Common Coagulants

COAGULANT	pH
Aluminum sulfate	5.0 to 7.0
Ferrous sulfate	9.5 and above
Chlorinated copperas	4.0 to 6.5 and above 9.5
Ferric chloride	4.0 to 6.5 and above 9.5
Ferric sulfate	4.0 to 10.0

3. Add 0.5 ml of standard coagulant solution to one sample of raw water, 1.0 ml to the second sample, 2.0 ml to the third sample, 3.0 ml to the fourth sample, 4.0 ml to the fifth sample, and 5.0 ml to the sixth sample. The result is a dosage of 5, 10, 20, 30, 40, and 50 mg/l, respectively.

4. Agitate samples in the jar test apparatus at a velocity about equal to the treatment equipment you are using and for the same length of time as the treatment equipment mixing time.

5. Keep the samples at the same temperature as water passing through your treatment equipment.

6. After stirring, let the samples settle for 30 minutes.

7. Siphon off a sample of the supernatant and determine the turbidity by using a turbidimeter.

8. The smallest amount of coagulant that produces the lowest turbidity represents the optimum dosage. Multiply the coagulant dosage in mg/l (step 5 above) by 8.33 to get the correct chemical feed in pounds per million gallons.

9. Repeat the steps for each chemical used until satisfactory results are obtained.

TURBIDITY TEST

Special instruments are available for measuring turbidity (fig. 7-18). These instruments greatly simplify the work of the operator performing a turbidity test. Results are reliable and accurate. Complete instructions are available from manufacturers of these instruments. In general, however, the principles of operation are the same. Usually an easy, five-step procedure is followed.

1. The sample tube is filled with the water to be tested.
2. The glass plunger is inserted in the tube.
3. The tube is placed in the instrument.

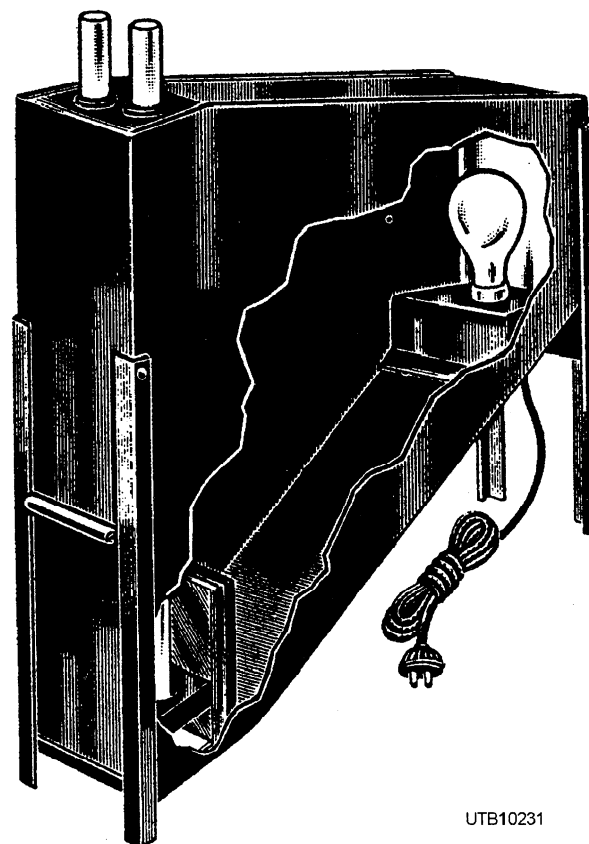


Figure 7-18.—Turbidimeter.

4. The dial at the side of the instrument is turned until the field seen in the eyepiece becomes uniform.

5. The value indicated on the dial is read and the turbidity content of the sample being tested is determined directly from a chart furnished with the instrument.

RECORDS

Results of all findings made in the laboratory should be recorded on laboratory data forms. Two forms for recording data are the Potable Water Supply and Distribution Operating Record and the Potable Water Treatment Plant Operating Record.

The Potable Water Supply and Distribution Operating Record are designed as a management tool for analysis of operating data and evaluation of the potable water supply and distribution performance. Complete instructions on the method of daily entries on this form are on its reverse side.

The Potable Water Treatment Plant Operating Record is designed as a management tool for the analysis of operating data and the evaluation of potable water treatment plant performance. A separate form should be prepared for each potable water treatment plant at an activity. Complete instructions on the method of daily entries on this form are on its reverse side.

Both of these records should be prepared in duplicate, and both should be summarized at the end of the month. The original should be retained on file and the carbon copy forwarded to the district public works officer not later than the tenth of the following month. Activity files should include records of the current and two preceding years.

Keep forms clean, concise, and hand print with a pencil or a pen so as not to smear. Information on forms must be understandable and legible for future reference. Constant reference is made to the data as a means of checking and increasing plant efficiency. It provides a control measure to obtain the maximum efficiency of

operation and to SAVE, not WASTE, chemicals used in water treatment.

- Q16. Why is water analysis, through water testing, done during treatment?*
- Q17. What are the two types of water tests used to determine chlorine residual?*
- Q18. On the pH scale, what does a reading of 7 indicate?*
- Q19. You are performing a chloride test and have used 2.5 ml of AgNO_3 in a 25 ml water sample . What will the ppm of chloride be?*
- Q20. What is the purpose of the jar test?*